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16. ABSTRACT: The major objectives of the HAZCON Solidification SITE Program Demonstration Test were to develop reliable performance and cost information. The demonstration occurred at a 50-acre site of a former oil reprocessing plant at Douglassville, PA containing a wide range of organic and heavy metal contaminants. The HAZCON process mixes the hazardous waste material with cement, a proprietary additive called Chloranan and water. The Chloranan is claimed to neutralize the inhibiting effect that organics normally have on the hydration of cement.

The technical criteria used to evaluate the effectiveness of the HAZCON process were contaminant mobility, based on leaching and permeability tests; and potential integrity of solidified soils, based on measurements of physical and microstructural properties.

Extensive sampling and analyses were performed showing 1) the concentration of the organics were the same in the leachates of the untreated and treated soils, 2) heavy metals reductions were achieved, and 3) structural properties of the solidified cores were found to indicate good long-term stability.

Cost per ton of contaminated soil at the Demonstration Test conditions was determined approximately $200. Given projected system improvements and adjustments of critical variables such as chemical additives, on-line factor, and equipment capacity, this cost was estimated to range as low as $90.

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Volume I

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VOLUME I
TECHNOLOGY EVALUATION REPORT SITE PROGRAM DEMONSTRATION TEST HAZCON SOLIDIFICATION DOUGLASSVILLE, PENNSYLVANIA

by

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NOTICE

The information is this document has been funded by the U.S. Environmental Protection Agency under Contract No. 68-03-3255 and the Superfund Innovative Technology Evaluation (SITE) Program. It has been subjected to the Agency's peer review and administrative review and it has been approved for publication as a USEPA document. Mention of trade names or commercial products does not constitute an endorsement or recommendation for use.

FOREWORD

The Superfund Innovative Technology Evaluation (SITE) program was authorized in the 1986 Superfund amendments. The program is a joint effort between EPA's Office of Research and Development and Office of Solid Waste and Emergency Response. The purpose of the program is to assist the development of hazardous waste treatment technologies necessary to implement new cleanup standards which require greater reliance on permanent remedies. This is accomplished through technology demonstrations which are designed to provide engineering and cost data on selected technologies.

This project consists of an analysis of Hazcon's proprietary solidification process and represents the second field demonstration in the SITE program. The technology demonstration took place at a former oil reprocessing plant which comprises the Douglassville Superfund site. The demonstration effort was directed at obtaining information on the performance and cost of the process for use in assessments at other sites. Documentation will consist of two reports. This Technology Evaluation Report describes the field activities and laboratory results. An Applications Analysis will follow and provide an interpretation of the data and conclusions on the results and potential applicability of the technology.

Additional copies of this report may be obtained at no charge from EPA's Center for Environmental Research Information, 26 West Martin Luther King Drive, Cincinnati, Ohio, 45268, using the EPA document number found on the report's front cover. Once this supply is exhausted, copies can be purchased from the National Technical Information Service, Ravensworth Bldg., Springfield, VA, 22161, (702) 487-4600. Reference copies will be available at EPA libraries in their Hazardous Waste Collection. You can also call the SITE Clearinghouse hotline at 1-800-424-9346 or 382-3000 in Washington, D.C. to inquire about the availability of other reports.

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ABSTRACT

The major objectives of the HAZCON Solidification SITE Program Demonstration Test were to develop reliable performance and cost information. The demonstration occurred at a 50-acre site of a former oil reprocessing plant at Douglassville, PA containing a wide range of organic and heavy metal contaminants. The HAZCON process mixes the hazardous waste material with cement, a proprietary additive called Chloranan, and water. The Chloranan is claimed to neutralize the inhibiting effect that organics normally have on the hydration of cement.

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Extensive sampling and analyses were performed showing 1) the concentration of the organics were the same in the leachates of the untreated and treated soils, 2) heavy metals reductions were achieved, and 3) structural properties of the solidified cores were found to indicate good long-term stability.

Cost per ton of contaminated soil at the Demonstration Test conditions was determined at approximately $205.

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* Volume II contains four appendices: Operating Log Data; Sampling and Analytical Report; a Consultant's Report: Characterization of HAZCON Samples by Scanning Electron Microscopy, Optical Microscopy, and X-ray Diffraction; and Data Reduction Calculations

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In addition, we extend our appreciation to Mr. Timothy Smith from HAZCON Engineering, Inc.; and contributors from Radian Corporation, and Scientific Waste Strategies, Inc.

SECTION 1

INTRODUCTION

1.1 BACKGROUND

In response to the Superfund Amendments and Reauthorization Act of 1986 (SARA), the Environmental Protection Agency's Offices of Research and Development (ORD) and Solid Waste and Emergency Response (OSWER) have established a formal program to accelerate the development, demonstration, and use of new or innovative technologies as alternatives to current containment systems for hazardous wastes. This new program is called Superfund Innovative Technology Evaluation or SITE.

The major objective of a Demonstration Test Program is to develop reliable cost and performance information on innovative alternative technologies so that they can be adequately considered in Superfund decision making. Common measurement, monitoring, and evaluation guidelines and protocols were developed by ORD and used to collect the data and information from the demonstration.

One technology, which was demonstrated at the Douglassville, PA Superfund Site, is the HAZCON proprietary solidification process. The process involves the mixing of hazardous waste material and cement with a patented nontoxic chemical (as claimed by HAZCON) called Chloranan. The Chloranan is claimed to neutralize the inhibiting effect that organic contaminants normally have on the crystallization of cement-based materials. For this treatment, the wastes are immobilized and bound by encapsulation into a hardened, leach-resistant concrete-like mass.

The Douglassville site, No. 102 on the National Priority List, is located along the Schuylkill River in Berks County, Pennsylvania. The site is approximately 5 miles west of Pottstown and 11 miles southeast of Reading. This rural 50-acre oil recovery facility includes two large lagoons once filled with oily sludge, an oily filter cake disposal area, an oil drum storage area, an area where generated sludge was landfarmed into the soil, and the plant processing area.

More than 250,000 cu yd of soil is contaminated with the following constituents:

Oil and grease
Polychlorinated biphenyls (PCBs)
Toluene
Benzene
Xylenes

Phenols
Ethylbenzene
Tetrachloroethylene
Base neutral/acid extractables (BNAs)
Polycyclic aromatic hydrocarbons (PAHs)
Heavy metals (primarily lead)

In 1941, Berks Associates, Inc. began waste oil recycling operations at the site. Waste generated from this process was stored in two lagoon areas located in the northwest and northeast quadrants. In November of 1970, ten days of heavy rain caused the overflowing of the lagoons and the breaching of safety dikes, releasing two to three million gallons of oily sludge.

The broken dikes were repaired and a federal order was issued, stating that no more residual oil was to be stored in the lagoons. Federal and State actions were taken to dispose of the remaining oily sludge. Before this action could be carried out, tropical storm Agnes occurred in June of 1972 and caused the Schuylkill River to overflow its banks and inundate the entire lagoon complex. An estimated six to eight million gallons of oily sludge were released and carried downstream for about 15 miles by floodwaters. During cleanup after the storm, the lagoons were drained and backfilled.

Berks Associates, Inc. continued the oil recycling operations until 1979 when the owner determined that the corrections mandated by the Pennsylvania Department of Environmental Resources (PADER) were cost-prohibitive. Operations then turned to refining waste oils for use as fuel in industrial boilers. Beginning in 1979, oily waste sludge from the new recycling process was landfarmed in the area of the old western lagoon. This practice was halted in 1981 when PADER mandated operational corrections to the landfarm configuration.

From September 1979 to April 1982, Berks Associates, Inc. allowed Reclamation Resources, Inc. to store 730 drums of solvents and wastewaters on site. PADER found that several of these drums were leaking onto the surface soil during storage, and in April 1982, the drums were removed. Plant activities ceased in December 1985.

1.2 PROGRAM OBJECTIVES

The major objectives of this SITE Program, utilizing the HAZCON solidification technology at the Douglassville Superfund Site, were to determine the following:

1. Ability of the stabilization/solidification technology to immobilize the site contaminants, primarily polychlorinated biphenyls (PCBs), volatile organics, base neutral/acid extractables (BNAs), oil and grease, and heavy metals (primarily lead).

2. Effectiveness of the technology for treating soil with contaminant concentrations varying over the range 1-25% by wt. oil and grease.

3. Performance and reliability of the process system.

4. Long-term stability and integrity of the solidified contaminated soil.

5. Costs for applying the technology to commercial size or Superfund sites.

1.3 TECHNOLOGY EVALUATION CRITERIA

The following technical criteria were used to evaluate the effectiveness of the HAZCON process for immobilizing the contaminants in the soils at the Douglassville site:

1. Mobility of the contaminants:
    a. Leachability of the contaminants and oil and grease before and after treatment
    b. Relative permeability of the treated and untreated soil

2. Integrity of the solidified soil mass:
    a. Unconfined compressive strength
    b. Macro properties
    c. Microstructural changes

The above criteria were used to develop the sampling program described in Section 6; an explanation is provided in the following paragraphs.

The leachability of the metals and organics should be reduced due to binding within the cement structure and also due to the reduced surface area of a solidified sample. Three leachability tests were performed: the Toxicity Characteristic Leaching Procedure (TCLP), which required grinding of the solidified treated soil, and leaching tests MCC-1P and ANS 16.1, which simulate the solidified condition that exist after soil treatment.

Relative permeability is a measure of the rate of movement of water passing through a soil mass, thus an indication of the quantity of water contacting the contaminants in the treated and untreated soil. Typical unconsolidated soils have a permeability of 10^{-2}-10^{-3} cm/sec. A reduction to 10^{-7} cm/sec or less would indicate that the HAZCON process produced a highly impermeable solidified mass.

Unconfined compressive strength is an indirect measure of the interaction of the cement-based additive with the organics in the soil. A low compressive strength may be indicative of inhibition of the normal setting reactions.

Treated soil integrity is a qualitative factor related to internal fracturing within the solidified mass, and measurable by the ability to survive freeze/thaw and wet/dry weathering cycles, and to maintain physical integrity over time. Since freeze/thaw and wet/dry weathering tests were performed on the solidified soil samples, followed by unconfined compressive strength tests, some quantitative measure was obtained on long-term treated soil integrity. In addition, a long-term monitoring program exists to provide input on the integrity of the solidified blocks over a five-year period.

Solidified hazardous wastes are multiphased materials whose microstructure influences their leaching behavior and long-term stability. Since pozzolanic setting reactions are complex, it is important to characterize the microstructure to identify potential durability problems. Small-scale non-homogeneities or porosity could lead to degradation of mechanical properties over time and allow the release of contaminants. Treated soil samples were characterized by using scanning electron microscopy (SEM) and x-ray diffraction. These techniques provided information about specimen porosity, uniformity and degree of mixing, mineral content, degree of hydration of the cement, and the presence of unaltered waste material.

1.4 DESCRIPTION OF OPERATIONS

Contaminated soils from six plant areas were processed by the HAZCON Mobile Field Blending Unit (MFU). Sufficient feedstock was utilized from five areas to produce from each 5 cu yd of treated soil and from the sixth area to produce 25 cu yd. The purpose of the latter extended run was to obtain information on equipment reliability. The six areas, whose locations are shown in Figure 4.2, are defined as follows:

Drum Storage Area	DSA	5 cu yds
Lagoon North	LAN	5 cu yds
Filter Cake Storage Area	FSA	5 cu yds
Landfarm Area	LFA	5 cu yds
Plant Facility Area	PFA	5 cu yds
Lagoon South	LAS	25 cu yds

The process involves the blending of the contaminated soil, cement, water, and the proprietary additive Chloranan. All soil feedstocks were taken from the top 12 inches of soil, with the exception of LAN, where the feed was excavated from a depth of 1-2 feet. The soil then was screened to remove rocks and debris greater than 3 inches in diameter. Utilizing a front-end loader, the soil was brought to the MFU where it was fed to the waste bin hopper. A cement feed hopper, intermittently fed from an on-site cement truck, also was mounted on the MFU. Chloranan and water were provided from tanks on a support vehicle. The four components were blended in a 9-in diameter mixing screw. For the five shorter runs, the blended slurry was fed to five 1-cu-yd wooden molds. For the extended run, the slurry was fed to two large pits, each 8 ft x 16 ft x 3 ft, and three 1-cu-yd molds.

During feedstock processing, the excavation holes were enlarged to accommodate burial of treated blocks that have grown in size by approximately 100%. Before the blocks for a particular feedstock were buried, the hole was lined with plastic to prevent seepage in of contaminated water, and a 1-ft layer of clean soil was deposited. After the blocks were placed in the excavation hole, additional clean soil was added to cover the blocks. Stakes were planted to identify the location of each block.

Untreated soil samples from 12 parts of each feedstock were collected and composited for analysis. Slurry samples were collected for analysis after 7 days of curing. Finally, core samples, after they had cured for more than 28 days in the field, were taken from the same blocks as the slurry samples.

1.5 PROJECT ORGANIZATION

For the SITE Program Demonstration a Cooperative Agreement was signed between EPA and HAZCON, Inc. HAZCON was responsible for operating their equipment and providing the chemical additives. EPA, through its contractor, Enviresponse, Inc., prepared the Demonstration Plan, performed the test site preparation, arranged for the sampling and analyses, evaluated the data, and prepared the Technology Evaluation Report.

Enviresponse utilized the services of Radian Corporation for the sampling and analysis work. Radian is headquartered in Austin, TX, with additional laboratory facilities in Perimeter Park, NC and Sacramento, CA. In addition, Enviresponse employed Scientific Waste Strategies, Inc. (SWS) of Baton Rouge, LA both as consultant and to perform the microstructural studies. SWS consists of three Louisiana State University professors with expertise in hazardous waste treatment utilizing cement-based stabilization/solidification processes.

SECTION 2

SUMMARY OF RESULTS

The program obtained a large amount of analytical and operating data and was able to meet the five objectives described in Section 1.2. A summary of the results, which respond to the program objectives, are summarized below.

1. The six plant areas offered a wide range of feeds. The oil and grease levels ranged from 1-25% by wt., and polychlorinated biphenyls (PCBs) were detected up to 52 ppm by wt. High concentrations of lead (up to 23,000 ppm by wt.) were measured along with lower levels of chromium and zinc. Volatile organic concentrations in excess of 100 ppm by wt. and semivolatiles, particularly phenols, at soil concentrations in excess of 500 ppm by wt., were measured at FSA. For the other five areas the total concentration for volatile organics and semivolatiles combined was less than 100 ppm by wt.

2. The volume of the solidified soils upon treatment increased by approximately 120%, at feedstock moisture levels up to 25%, the maximum measured at the site. HAZCON can reduce the volume increase by optimizing the quantity of additives. However, other physical and chemical properties of the treated soil may change.

3. The unconfined compressive strengths of the solidified cores ranged from 220-1570 psi, and the values were inversely related to the level of oil and grease. These are quite satisfactory levels from a structural strength viewpoint.

4. Permeabilities of the solidified soils were very low, 10^{-8}-10^{-9} cm/sec, which is well below the 10^{-7} cm/sec value that is considered in the hazardous waste disposal industry to be acceptable for soil barrier liners.

5. The weathering tests showed only small losses in weight for both the test specimens and controls, about 1% by wt. Unconfined compressive strength tests performed on the weathered test specimens and controls showed values equivalent to those obtained for the standard test specimens described in item 3.

6. The TCLP leaching tests of the solidified soils

indicated very low levels of metals, volatiles, and semivolatiles in the leachates. Essentially all values were below 1 ppm.

For the metals, lead is the predominant component. The leachate concentrations for all but DSA for untreated soil was 20-50 mg/l. For treated soils this was reduced below 100 ug/l.

For volatile organics, the leachate concentrations were primarily in the range of 50-1000 ug/l, in both the untreated and treated soils.

The leachate concentrations of BNAs were equivalent for untreated and treated soils. Various phenols were the primary contaminant with concentrations ranging as high as 3-4 mg/l for FSA.

Oil and grease leachate concentrations were greater for each of the treated soils compared to the untreated soils. The treated soil values were typically 2-4 mg/l, for soil concentrations approximately 40% of that of the untreated soil, while the untreated soil was less than 2 mg/l.

7. Leaching tests ANS 16.1 and MCC-1P were each performed on one treated soil sample from each area except DSA and LFA. Experience with these tests on hazardous wastes is limited. Comparisons to the treated soil TCLP results are made, but the significance of any differences is unclear. The results from these leach tests are as follows:

   o Metals

     - MCC-1P produced leachate concentrations greater than TCLP concentrations. ANS 16.1 results were comparable to the TCLP extracts from treated soil cores.
     - Concentrations increased with time interval of leaching.

   o Volatile Organics (VOC)

     - MCC-1P leachates had larger VOC contents then ANS 16.1 leachates and were comparable to the TCLP leachates.
     - Discernible trends of concentration versus leach time (3 to 28 days) were not observed.

   o Base Neutral/Acid Extractables (BNAs)

     - MCC-1P leachates had greater BNA

concentrations than ANS 16.1 leachates and were comparable to TCLP leachates.
  - Leachate concentrations for the phenols, the predominant BNA in a few of the samples, appeared to increase with time (3 to 28 days) in MCC-1P but not in ANS 16.1.

These results showed that the concentrations of the various analytes in the leachates, from uncrushed core samples, are approximately equal to that from the TCLP leach test. They also confirm the trends seen from the TCLP leach test on contaminant mobility.

8. Polychlorinated biphenyl concentrations in all leachates, whether for treated or untreated soils, were below the detection limits of 1 ug/l.

9. Microstructural analyses are proven methods for understanding the mechanisms of structural degradation of soil, cements, and soil-cement mixtures and each of these with inorganic and organic compounds. However, there has been relatively few studies of the microstructure of complex waste/soil mixtures like those resulting from stabilization/solidification procedures. Consequently, in some cases, interpretation of microstructural observations may be difficult. The microstructural analyses showed the following:

   - o The contaminant immobilization appears to show that encapsulation is a major part of the mechanism of solidification/stabilization. This is supported by the facts that 1) brownish aggregates passed through the soil unchanged, and 2) peaks in the x-ray diffraction patterns for both the soil and cores could not be identified with any expected minerals.
   - o The solidified soils and buried blocks (28-day), were very porous.
   - o The mixing of the four process components, soil, cement, Chloranan, and water, was not highly efficient. Four factors support this: 1) brownish aggregates do not disaggregate, 2) there is more than expected unhydrated cement, 3) there are globules of dark colored material in the cores, and 4) there are many pores.

10. The operations for the first five runs (5 cu yd) required many startups due to unscheduled shutdowns caused primarily by plugging in the soil feed screw.

In addition, the consistency of the slurry mix was quite variable, running the gamut from powdery to a very thin slurry. However, physical property changes due to this variation were not observed. For the extended time run (25 cu yd) at LAS, operation was more uniform, with only a few short-term outages.

11. The economic analsyis was based on the 70% on-stream factor and a 300 lb/min operating capacity observed for the HAZCON Mobile Field BLending Unit. A cost of \$205/ton was calculated during the Douglassville, Pa. demonstration. The process is very intensive in labor and chemical additives, with these items amounting to approximately 90% of the total costs. Substantial cost reductions are expected with process and chemical optimization.

SECTION 3

PROCESS DESIGN

3.1 PROCESS DESCRIPTION

HAZCON, Inc.'s Mobile Field Blending Unit (MFU) is a continuous processing unit and operates as shown in the flow diagram, Figure 3.1.

Operating capacities, though governed by predetermined mix ratios set in the laboratory, are variable up to 15 cu yd of processed raw waste per operating hour. The MFU has no external utility requirements other than a standard water hookup and the attachment of a "quick connect" line from a bulk cement carrier.

The MFU accepted soil feedstock from a front-end loader to the onboard waste bin. The soil was fed by a variable-speed calibrated 8-in diameter feed screw to the 9-in diameter screw blender. Simultaneously, cement from a second MFU storage bin was also fed by a variable-speed screw feeder to the blender. The water and Chloranan, from auxiliary vehicle tanks, were pumped at controlled capacities to the inlet of the blender for blending with the soil and cement. The mixed slurry was then fed to containment molds for solidification into blocks.

Equipment calibration was performed each time a new waste feed matrix entered the MFU. Calibration involved the determination of the waste feed rate by weight, then setting the cement and Chloranan rates at appropriate ratios to the contaminated soil. Water was added as required.

3.2 EQUIPMENT SPECIFICATIONS

Bin, tank, auger sizes, and component locations are shown on the attached equipment layout diagram, Figure 3.2.

A separate bulk cement carrier was provided for feeding to the cement bin on the equipment trailer carrying the MFU. A water supply truck was provided for process water and for feeding high pressure equipment decontamination water. In addition, Chloranan was supplied from a tank on the auxiliary trailer provided by HAZCON.

Photographs of the equipment at various process stages are shown in Figures 5.1-5.6.

3.3 PROCESS SCHEME

The following steps are illustrated in Figure 3.1.

- Waste material was introduced to the system through the use of earth moving equipment.
- The waste was moved through the process in a controlled flow, allowing for precise measurement of the material. The contaminated soil was fed to the mixer by a calibrated screw feeder.
- Based upon these measurements, blending ratios, which were predetermined by HAZCON, were set on a time-weighted basis for both the Chloranan and a pozzolanic material such as No. 1 Portland cement.
- The pozzolanic ingredient was stored in a hopper and then metered into the mix by a calibrated screw feeder. Typical waste-to-pozzolan ratios, on a weight basis, range from 1:1 to 3:1. For the test at the Douglassville site, a 1:1 ratio was used.
- Chloranan was stored in a holding tank, then pumped into the mixing chamber. Through precise control of the flow rate, ratios of waste to Chloranan can be accurately metered from a 10:1 to a 50:1 blend. For the Demonstration Test, the ratio was approximately 10:1.
- After initial combination of the primary ingredients, water was added as necessary to achieve the most desirable slump on the mix, based upon visual inspection by HAZCON.
- For the three soil feeds that were spiked with toluene the injection point was at the inlet of the blending auger.
- All additives were fed via pump or auger through a mixing chamber to achieve a homogenous blend.
- The resultant mass was extruded into either temporary or permanent molds.

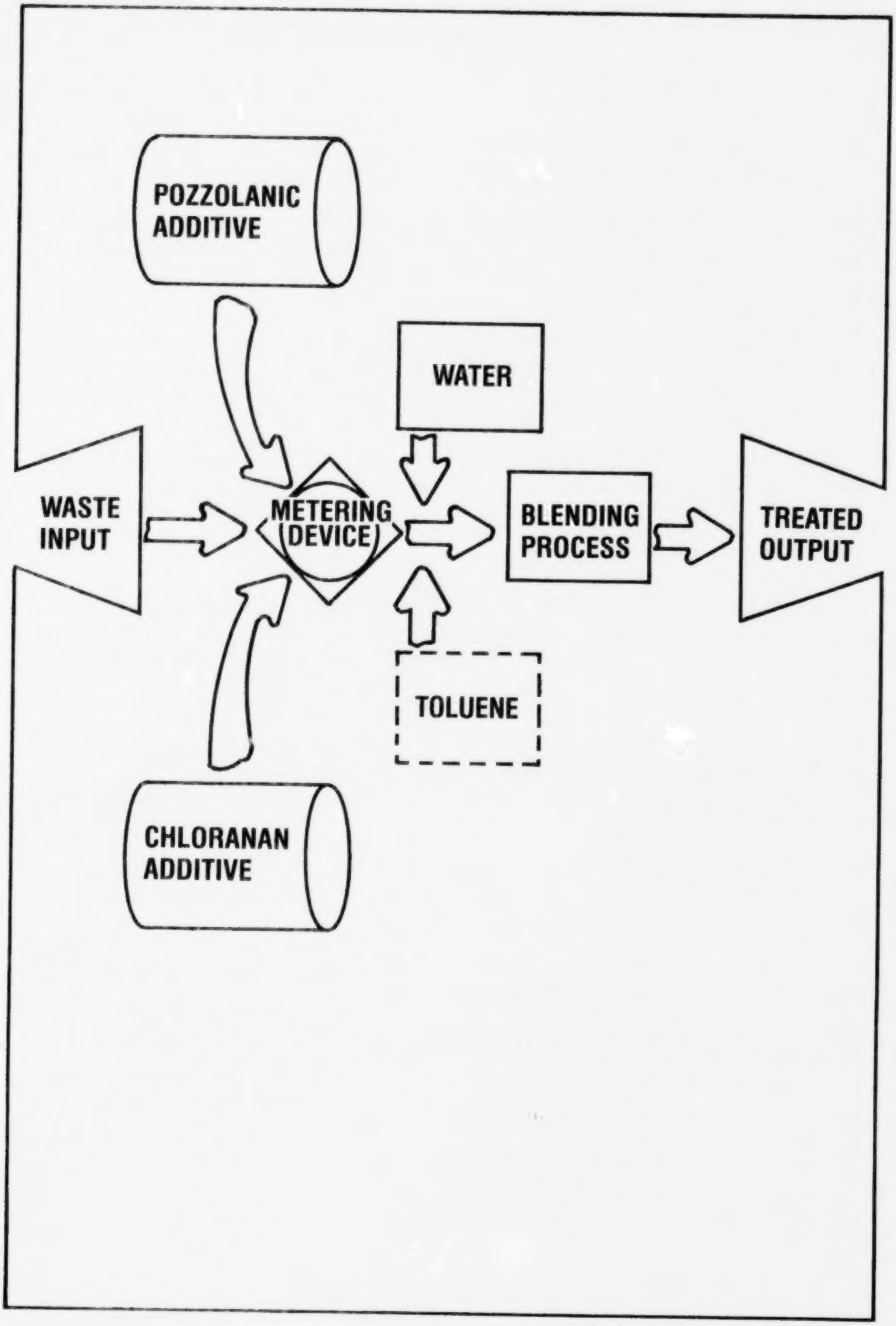
POZZOLANIC ADDITIVE
WATER
WASTE INPUT
METERING DEVICE
BLENDING PROCESS
TREATED OUTPUT
TOLUENE
CHLORANAN ADDITIVE

Figure 3.1. Flow diagram.

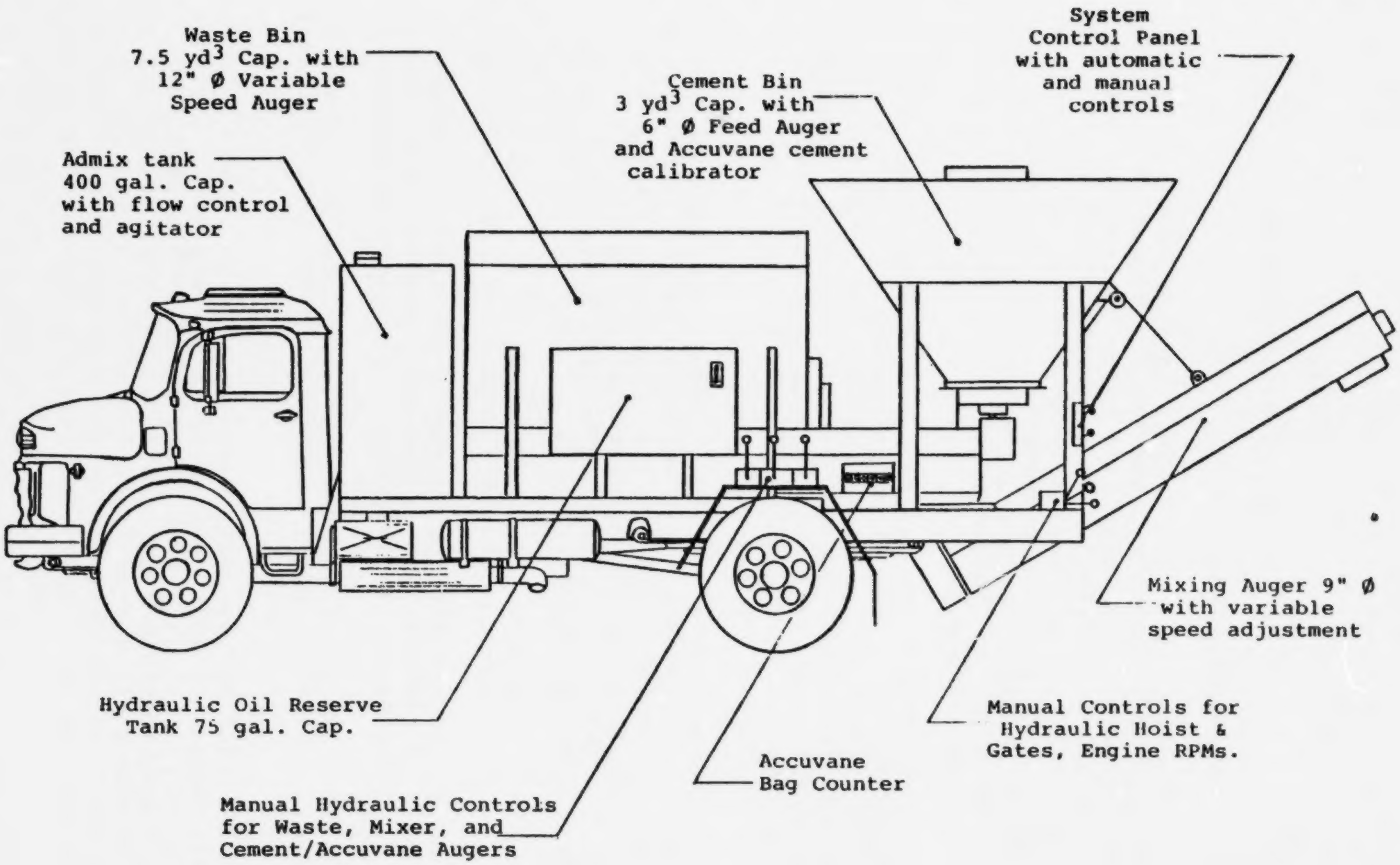
Waste Bin
7.5 yd3 Cap. with
12" Ø Variable
Speed Auger
Admix tank
400 gal. Cap.
with flow control
and agitator
Cement Bin
3 yd3 Cap. with
6" Ø Feed Auger
and Accuvane cement
calibrator
System
Control Panel
with automatic
and manual
controls
Mixing Auger 9" Ø
with variable
speed adjustment
Hydraulic Oil Reserve
Tank 75 gal. Cap.
Manual Controls for
Hydraulic Hoist &
Gates, Engine RPMs.
Accuvane
Bag Counter
Manual Hydraulic Controls
for Waste, Mixer, and
Cement/Accuvane Augers

Figure 3.2. Equipment layout diagram.

SECTION 4

TEST SITE DESCRIPTION

4.1 SITE CHARACTERISTICS

The Douglassville site is located in a rural setting surrounded by croplands and light residential and industrial development. The Schuylkill River borders the site to the north and to the east. This stretch of the river lies within the boundaries designated by the Pennsylvania Scenic Rivers Act of 1972 and is a component of the Pennsylvania Scenic Rivers System. It is required that the quality and quantity of the river and adjacent waters be adequate for recreation and fish propagation.

EPA Region III sampling in April of 1982 found groundwater contaminants in the oil reprocessing facility drinking water well. These contaminants included 1,2-trans-dichloroethylene, trichloroethylene,and 1,1,1-trichloroethane. Compounds such as trichloroethylene and benzene were found in an on-site drainage swale. Lead and PCBs were found in on-site sediments.

The two wastewater settling lagoons, located on approximately seven acres of the site, were drained and backfilled after the major flooding in 1972. The remaining oil and solvent-stained surface soils in the oil processing area and the oily sludge in the backfilled lagoons potentially may cause three major environmental results:

- Contamination of groundwater aquifers through the migration and infiltration of hazardous substances
- Toxic effects to people and the environment through contact with contaminated surface water runoff or through consumption of contaminated groundwater
- Contaminant loading of the Schuylkill River via surface water runoff, flooding, or groundwater discharge

Understanding the geology at the site is required to determine the routes by which contaminants may migrate. Geologic features that influence the flow of groundwater in unconsolidated materials and bedrock aquifers are of concern. The character and distribution of soil types also is significant in determining whether contaminants are retained on site or are transmitted into the general environment.

The Douglassville Superfund Site is situated in the Triassic Lowland section of the Piedmont Province. It includes a Triassic section many thousands of feet thick. The rocks range from shales to coarse limestone conglomerates. Groundwater flow is controlled by secondary permeability; water flow takes place along joints, faults, and especially bedding planes. Transmissivity ranges from 500 to 1000 gallons per day per foot (gpd/ft). The groundwater within the area is of calcium bicarbonate type, ranging from moderately hard to very hard. Total dissolved solids are about 300 ppm.

Groundwater and geological investigations at the site were obtained during a Remedial Investigation/Feasibility Study (RI/FS) [1], which consisted of drilling 25 boreholes at 13 locations. At each of the 13 drill sites a deep and a shallow well were completed so that groundwater in the overburden and the bedrock could be observed. The deep wells penetrated 40-50 feet below the surface and the shallow wells penetrated 10-20 feet. In addition, test pits were excavated to obtain additional subsurface data. See Figure 4.1 for the locations of these initial borings and excavations. As of May 1988, there is another RI/FS in progress.

Site geology generally consists of 10 to 20 feet of overburden, made up of topsoil, alluvium, waste material, and backfill material in overlying lagoon areas. Underlying bedrock is composed of red shale, siltstone, and some fine sandstone. Groundwater flows in a north to northeast direction toward the Schuylkill River. Transport through groundwater is potentially the most significant mechanism of contaminant migration at the Douglassville Superfund Site.

Water level data provide a picture of the groundwater regime. Data were collected in August and September, 1984, and in March and January, 1985. Water levels in all wells generally declined 3 to 4 feet over the September to January monitoring interval, and rose between 0.5 and 2.4 feet by March 1985.

Despite these fluctuations in water levels, the highest measured water level elevations indicate that the groundwater may not reach the known lower depths of subsurface waste materials.

Permeability of subsurface materials affects the rate of groundwater movement. The alluvial materials at the site range in permeability from 1.8×10^{-3} centimeters/second (cm/sec) to 1.3×10^{-2} cm/sec. This range represents average values determined from five of the alluvial wells, and is characteristic of fine to coarse-grained unconsolidated material.

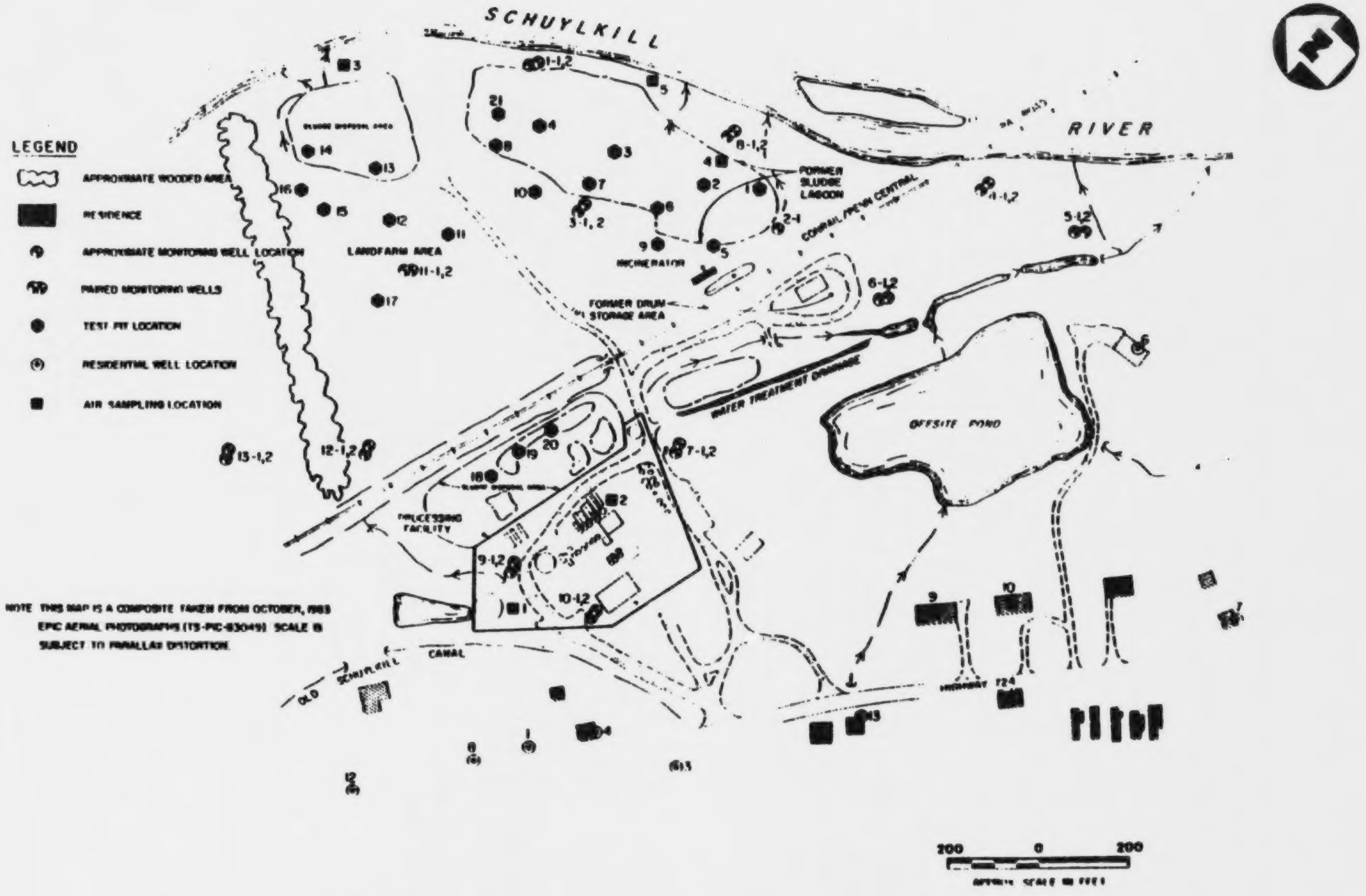
SCHUYLKILL RIVER
LEGEND
APPROXIMATE WOODED AREA
RESIDENCE
APPROXIMATE MONITORING WELL LOCATION
PAIRED MONITORING WELLS
TEST PIT LOCATION
RESIDENTIAL WELL LOCATION
AIR SAMPLING LOCATION
SLUDGE DISPOSAL AREA
LANDFARM AREA
FORMER SLUDGE LAGOON
CONRAIL/PENN CENTRAL
INCINERATOR
FORMER DRUM STORAGE AREA
WATER TREATMENT DRAINAGE
OFFSITE POND
PROCESSING FACILITY
OLD SCHUYLKILL CANAL
HIGHWAY 724
NOTE: THIS MAP IS A COMPOSITE TAKEN FROM OCTOBER, 1983 EPIC AERIAL PHOTOGRAPHS (TS-PIC-83049). SCALE IS SUBJECT TO PARALLAX DISTORTION.
200 0 200
APPROX. SCALE IN FEET
1-1,2
2-1
3-1,2
5-1,2
6-1,2
7-1,2
8-1,2
9-1,2
10-1,2
11-1,2
12-1,2
13-1,2

Figure 4.1. Subsurface soil, air, and groundwater sampling locations, Douglassville Site, based on RI/FS.

Permeability values measured within the Triassic bedrock differ greatly, supporting the theory of highly variable permeability in a fracture-dominated aquifer flow system. These values ranged from 2.8 x 10^{-1} to 5.2 x 10^{-5} cm/sec. The higher permeability value apparently reflects a high fracture/joint flow conduit located centrally in the site, beneath the former sludge lagoon area. Other high permeability values within the bedrock are found in the area of the oil processing facility. The lowest value appears to be at the eastern area of the site. The alluvial (overburden) material was generally more transmissive of water than the bedrock at each site. The highest transmissivity was 6600 gpd/ft and the lowest in the siltstone and shale was 80 gpd/ft.

4.2 SITE CONTAMINATION

The Douglassville Superfund Site covers approximately 50 acres. Seven acres of the site were formerly used as two lagoons, Lagoon North (LAN) and Lagoon South (LAS), to settle wastewater sludge generated by the facility's oil recycling process. After the flood in 1972, both lagoons were drained and backfilled. One of the former lagoons, located in the northwestern corner, is in an area where oil sludge was landfarmed (LFA) from 1979 through 1981. This area was unsuccessfully used for agricultural purposes between 1981 and 1984. The second lagoon was located in the northeastern corner of the site.

Located in the southern portion of the site are the recycling facility and office buildings (southwest). This is referred to as the Plant Facility Area (PFA). Just east of the PFA is a one acre area filled about 6-8 ft deep with oily filter sludge. This is called the Filter Sludge Storage Area (FSA). To the south, near the drainage ditch, is an area that was used for the storage of hundreds of drums of oil and oily water. This area is referred to as the Drum Storage Area (DSA). The drainage ditch flows into the Schuylkill River, which borders the northern and eastern sections of the site.

Relevant environmental media, i.e., air, surface water, surface soil, subsurface soil, soil screening, and groundwater, were sampled and analyzed to chemically characterize the site.

4.2.1 SURFACE SOIL

RI/FS data reveal that surface soil at the Douglassville Site is contaminated with PCBs, phthalate esters, polycyclic aromatic hydrocarbons (PAHs), pesticides, various volatile organics, and trace elements.

PCBs were detected in 11 of 16 surface soil samples. Concentrations of PCBs generally ranged from 38 micrograms per kilogram (ug/kg) to 24,000 ug/kg, except for one location in the filter cake storage area, which had PCB concentrations of 500,000 ug/kg.

PCBs were thus identified in soil samples from most areas of the site. The known environmental behavior of the PCBs leads to the conclusion that the occurrence of PCBs at these locations is probably attributable to direct deposition, migration by erosion of contaminated soil particles, and possibly to spills or drum leakage.

Various phthalate esters were identified in 9 of 16 surface soil samples. Concentrations of these compounds ranged from 170 ug/kg to 9,100 ug/kg.

The phthalate esters identified in soil samples were detected in areas where wastes were deposited, i.e., the former lagoon and landfarming areas, or where spills or leakage from drums may have occurred.

PAHs were identified in 2 of 16 surface soil samples. Concentrations of these compounds ranged from 93 ug/kg to 260 ug/kg. Thus, the contamination with these compounds is not extensive.

Volatile organic substances were identified in all surface soil samples at concentrations ranging from 51 ug/kg to 550 ug/kg. Volatile contamination of surface soil is not extensive.

Of the trace elements identified in site soil, arsenic, cadmium, chromium, lead, and mercury are of concern because of their known toxicity to human and environmental receptors. Concentrations of these elements encountered in site surface soil are quite low, except for lead, which is as high as 14,000 ppm.

4.2.2 SUBSURFACE SOILS

Subsurface soil samples were obtained from a number of the test pits excavated at the site. Subsurface soil contamination generally reflects the contamination detected in surface soil samples, although higher concentrations of volatile contaminants were identified. Test pits located in the former northeastern lagoon area, the northwestern area, and the northeast corner of the production facility were contaminated with lead, PCBs, and phthalate esters.

Three potential migration routes for subsurface soil contaminants have been identified:

- Infiltration of contaminants into the water table

- Subsequent convection of contaminants with flowing groundwater

- Convection to the surface with volatilizing organic compounds or other generated gases

4.2.3 SOIL SCREENING SAMPLES

Soil samples were taken in May of 1987 by Enviresponse Inc. [2] to chemically characterize the six areas proposed as feedstocks for the Demonstration Tests. Their locations are shown in Figure 4.2. The samples were taken from the top 12 inches of soil, except at LAN where the sample was taken at a depth of 1-3 feet. The feedstock location for the filter cake storage area was subsequently changed due to the inability of the filter cake to support the weight of the mechanical equipment required for excavation and sampling. The locations selected were near the highest contamination levels reported in the RI/FS. Where comparisons of the results to the RI/FS could be made at the two lagoons and the oily filter cake storage area, the results agreed with the RI/FS. The results are provided in Tables 4.1 - 4.5, showing that the concentration levels of volatile organics, BNAs, and PCBs are quite small, a few parts per million. These values are significantly less than the soil analyses taken during the Demonstration Test, which showed VOC concentrations up to 150 ppm and BNAs up to 500 ppm by weight.

4.2.4 SUMMARY

Based on the operational history of the site, as described in the RI/FS, with the placement of wastes in lagoons and sludge impoundments, subsurface soil was expected to show the greatest degree of chemical contamination and to represent the largest potential source for contamination of groundwater at the site. The occurrence and distribution of organic and inorganic substances confirmed the extensive contamination in subsurface soil samples obtained from the sludge disposal areas.

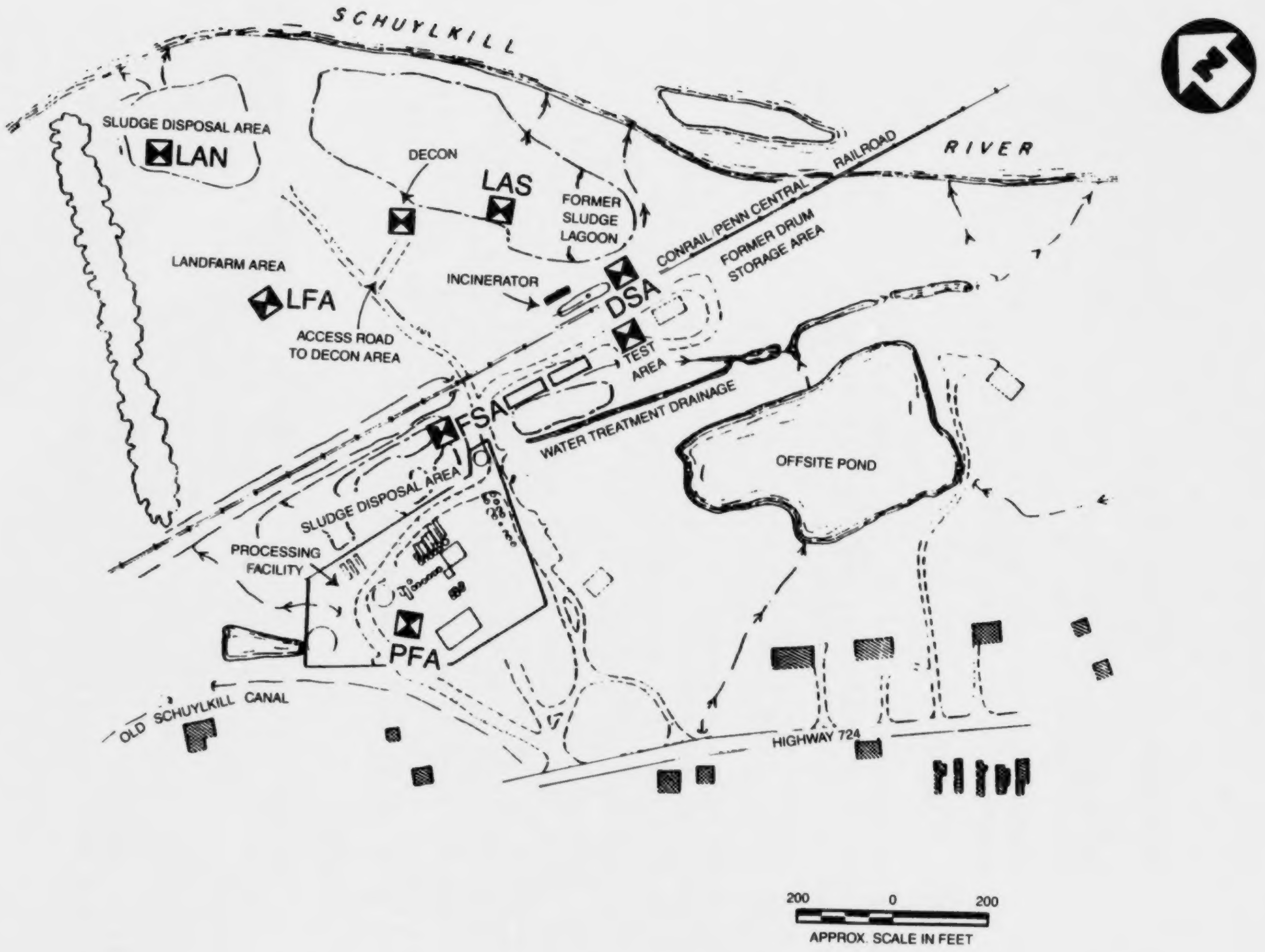
SCHUYLKILL
RIVER
SLUDGE DISPOSAL AREA
LAN
DECON
LAS
FORMER
SLUDGE
LAGOON
RAILROAD
CONRAIL/PENN CENTRAL
FORMER DRUM
STORAGE AREA
LANDFARM AREA
LFA
INCINERATOR
DSA
ACCESS ROAD
TO DECON AREA
TEST
AREA
WATER TREATMENT DRAINAGE
FSA
OFFSITE POND
SLUDGE DISPOSAL AREA
PROCESSING
FACILITY
PFA
OLD SCHUYLKILL CANAL
HIGHWAY 724
200
0
200
APPROX. SCALE IN FEET

Figure 4.2. Demonstration test sampling layout.

TABLE 4.1. RESULTS OF POLYCHLORINATED BIPHENYLS IN SOIL ANALYSIS

Sample Designation[a]	Concentration Aroclor 1260 (mg/kg)	Concentration Aroclor 1248 (mg/kg)
LAN	18.0	5.21
LFA	14.5	ND
LAS	15.8	5.29
PFA	8.64	5.12
DSA[b]	5.51	ND
FSA	23.4	ND

(a) The designations shown refer to the six plant area samples and are as follows:

LAN	Lagoon North
LFA	Landfarm Area
LAS	Lagoon South
PFA	Plant Facility Area
DSA	Drum Storage Area
FSA	Filter Cake Storage Area

(b) Represents the average of sample and duplicate run.

ND denotes not detected.

TABLE 4.2. RESULTS OF BASE NEUTRAL/ACID EXTRACTABLES IN SOIL ANALYSIS

BNA	DSA	FSA	LAN	LAS	LFA	PFA
	SAMPLE DESIGNATION					
NAPHTHALENE	ND	ND	ND	ND	ND	ND
FLUORENE	ND	ND	ND	ND	ND	ND
FLUORANTHENE	ND	ND	ND	ND	ND	ND
PYRENE	ND	ND	ND	ND	ND	[8.68]
BIS (2-ETHYLHEXYL) PHTHALATE	ND	ND	210*	ND	[9.62]	ND
BENZO (K) FLUORANTHENE	ND	ND	ND	ND	ND	[10.2]

* Sample concentrations reported in mg/kg of soil.

ND denotes not detected. Bracketed values are approximate because the concentration was below the level of quantification (LOQ).

TABLE 4.3. RESULTS OF VOLATILE ORGANICS IN SOIL ANALYSIS

VOC	LFA	FSA	DSA	LAN	PFA
METHYLENE CHLORIDE	ND	ND	ND	ND	ND
1,1-DICHLOROETHENE	ND	ND	ND	ND	ND
1,1-DICHLOROETHANE	ND	ND	ND	ND	ND
TRANS-1,2-DICHLOROETHENE	ND	ND	ND	ND	ND
CHLOROFORM	ND	ND	ND	ND	ND
1,2,-DICHLOROETHANE	ND	ND	ND	ND	ND
1,1,1-TRICHLOROETHANE	ND	ND	ND	ND	ND
CARBON TETRACHLORIDE	ND	3800(a)	ND	5600	ND
BROMODICHLOROMETHANE	ND	ND	ND	ND	ND
1,2-DICHLOROPROPANE	ND	ND	ND	ND	ND
TRANS-1,3-DICHLOROPROPENE	ND	ND	ND	ND	ND
TRICHLOROETHENE	ND	ND	ND	ND	ND
BENZENE	ND	ND	ND	ND	ND
DIBROMOCHLOROMETHANE*	ND	ND	ND	ND	ND
1,1,2-TRICHLOROETHANE*	ND	ND	ND	ND	ND
CIS-1,3-DICHLOROPROPENE*	ND	ND	ND	ND	ND
BROMOFORM	ND	ND	ND	ND	ND
1,1,2,2-TETRACHLOROETHANE*	ND	ND	ND	ND	ND
TETRACHLOROETHENE*	ND	ND	ND	[700]	ND
TOLUENE	ND	ND	ND	ND	ND
CHLOROBENZENE	ND	ND	ND	ND	ND
ETHYL BENZENE	ND	ND	ND	ND	ND
TOTAL XYLENES	ND	ND	ND	[1200]	ND

(continued)

(a) Sample concentrations reported in ug/kg of soil.

* - Denotes co-eluting compounds.

ND denotes not detected. Values in brackets are below the limit of quantification and considered approximate.

TABLE 4.3 (continued)

VOC	LAS	LAS
METHYLENE CHLORIDE	ND	ND
1,1-DICHLOROETHENE	ND	ND
1,1-DICHLOROETHANE	ND	ND
TRANS-1,2-DICHLOROETHENE	ND	ND
CHLOROFORM	ND	ND
1,2,-DICHLOROETHANE	ND	ND
1,1,1-TRICHLOROETHANE	[460]	[500]
CARBON TETRACHLORIDE	2900	2900
BROMODICHLOROMETHANE	ND	ND
1,2-DICHLOROPROPANE	ND	ND
TRANS-1,3-DICHLOROPROPENE	ND	ND
TRICHLOROETHENE	3100	3500
BENZENE	ND	ND
DIBROMOCHLOROMETHANE*	ND	ND
1,1,2-TRICHLOROETHANE*	ND	ND
CIS-1,3-DICHLOROPROPENE*	ND	ND
BROMOFORM	[1400]	[2100]
1,1,2,2-TETRACHLOROETHANE*	ND	ND
TETRACHLOROETHENE*	4100	4600
TOLUENE	4100	3000
CHLOROBENZENE	ND	ND
ETHYL BENZENE	2700	3500
TOTAL XYLENES	12000	14000

TABLE 4.4. RESULTS OF PRIORITY POLLUTANT METALS IN SOIL ANALYSIS

METAL	FSA	LFA	LAS	LAN	PFA	DSA
Hg	ND (5.0)	ND (5.0)	[13.]	[12.]	36.	18.
As	[52.]	ND (50.)	ND (50.)	[66.]	[65.]	[63.]
Se	ND (50.)	ND (50.)	ND (50.)	ND (50.)	ND (50.)	[82.]
Cd	ND (5.0)	ND (5.0)	ND (5.0)	ND (5.0)	[11.]	ND (5.0)
Zn	170.	870.	760.	250.	1800.	98.
Sb	300.	140.	240.	400.	650.	320.
Be	ND (0.5)	[1.0]	[0.5]	[0.5]	[1.0]	ND (0.5)
Ni	[8.3]	29.	31.	19.	75.	36.
Pb	4900.	6500.	9400.	8300.	16000.	8600.
Cu	120.	120.	170.	68.	510.	160.
Tl	ND (2.5)	ND (2.5)	ND (2.5)	ND (2.5)	ND (2.5)	ND (2.5)
Cr	[19.0]	40.	99.	120.	130.	64.
Ag	ND (5.0)	ND (5.0)	ND (5.0)	ND (5.0)	ND (5.0)	ND (5.0)

Results in ug/gm (dry weight)

ND denotes not detected. Values in () represent detection limit. [] denotes values below the lower limit of quantification (LOQ).

TABLE 4.5. RESULTS OF OIL AND GREASE IN SOIL ANALYSIS

SAMPLE	CONCENTRATION (ug/g)
DSA	23,000 (a)
FSA	317,000 (b)
LAN	358,000
LAS	126,000
LFA	76,800
PFA	54,200

(a) denotes average of 5 analyses.

(b) denotes average of 2 analyses.

SECTION 5

FIELD ACTIVITIES

The plans for the Demonstration Test are described in section 5.1. A summary of the actual operations is described in section 5.2. The few operational deviations from the Demonstration Plan are discussed in Section 5.3, along with some additions to the analytical testing program that were incorporated into the Program while at the site.

5.1 OPERATIONS PLAN

The overall operating procedure started with excavating the contaminated soil from the predesignated areas. These areas are illustrated on Figure 4.2. The feedstock was taken from the top 12 in, except at LAN where it was taken 1-3 feet below the surface. The soil then was screened to minus 3 in and transferred to the HAZCON unit by a front-end loader, with a 2 1/4 cu yd bucket. Two 12-part composite samples were taken from the bucket. The soil then was ready for feeding into the HAZCON Modified Field Blending Unit (MFU).

Before the start of each run, the soil, cement, and additive feed systems were calibrated and set to the proper rates. During the actual test, equipment operating data was taken.

During operation, slurry samples were taken in a long handled stainless steel pot. Since five 1-cu-yd molds were to be filled on all but the LAS run, samples were to be taken for blocks 1, 3, and 5 (deviations occurred - see section 5.2). Figure 6.1 shows the planned sampling scheme.

Soil excavations and soil sizing were performed on the same day that the soil was processed in the MFU. This was done to minimize loss of organic volatiles.

While the soil was being processed and cured, the excavation was enlarged to accept the cured blocks, with each pit at a depth of 4-5 feet. A nonporous plastic liner was placed in the pit covering the entire bottom and sides, and a 12-inch layer of clean fill was deposited on top of the liner. The solidified blocks were returned to the respective excavation holes 48-96 hours after treatment, and then the entire excavation area was back-filled with clean soil and identification stakes were placed over each block. The excess contaminated soil was spread in the immediate area, but well outside the lined excavation zone.

After curing for 28+ days, core samples were taken from the same blocks from which the slurry samples were collected, so that a known batch of slurry could be tracked. It is the intent of the Long Term Monitoring Plan to sample the surrounding clean soil to obtain a measurement of contaminants that may be leaching from the solidified blocks.

For the 25-cu-yd test, the three excavation holes for the treatment slurry were not located where the feedstock was taken. Since wooden molds (8 ftx16 ft) had to be fabricated and installed in the excavated holes to contain the slurry, the three excavation holes were dug to the northeast (Lagoon South) of the soil feedstock location two to three days before the test. The contaminated soil from the excavation holes was spread to the east of the excavation holes but still in LAS.

It had been anticipated that either two or three feedstocks per day would be processed. Between each feedstock treatment, the HAZCON MFU would be moved to the decontamination area at the northwest end of Lagoon South. The blending equipment would be flushed with high pressure water that would be allowed to drain onto the ground. Care would be taken to prevent the decontamination water from contaminating the Lagoon South feedstock. It was expected that the actual processing of each 5-cu-yd feedstock batch at the MFU would take 30-60 minutes. However, due to some minor operational problems only two feedstocks could be processed in a day. This is discussed in Section 5.3.

The 25-cu-yd test, originally intended to use feed from the Filter Cake Storage Area, but subsequently taken from Lagoon South, provided a more extended test run. For this test, the MFU was relocated closer to the feedstock source, near the decontamination area, as shown in Figure 4.2. The product slurry (except for three 1-cu-yd blocks) was returned directly to the excavation by a cement pump discharging through a 4-in diameter hose, both provided by HAZCON, Inc. The product feed rate was about the same as for the 5 cu yd tests.

Allowing 1 day for setup and 1 day for demobilization, the entire operational test period was expected to be 5 days. Actually the operation lasted 4 days. However, HAZCON demobilized on the last operating day, and the total test program time at Douglassville, exclusive of site preparation which included burying and covering the test blocks, was 5 days as planned.

Photographs from the operation and sampling work are shown in Figures 5.1-5.6.

Information was logged in a notebook to report the sampling operations and the overall operations at the site. This included the following:

- Notes on daily preparations of HAZCON and EPA
- Problems

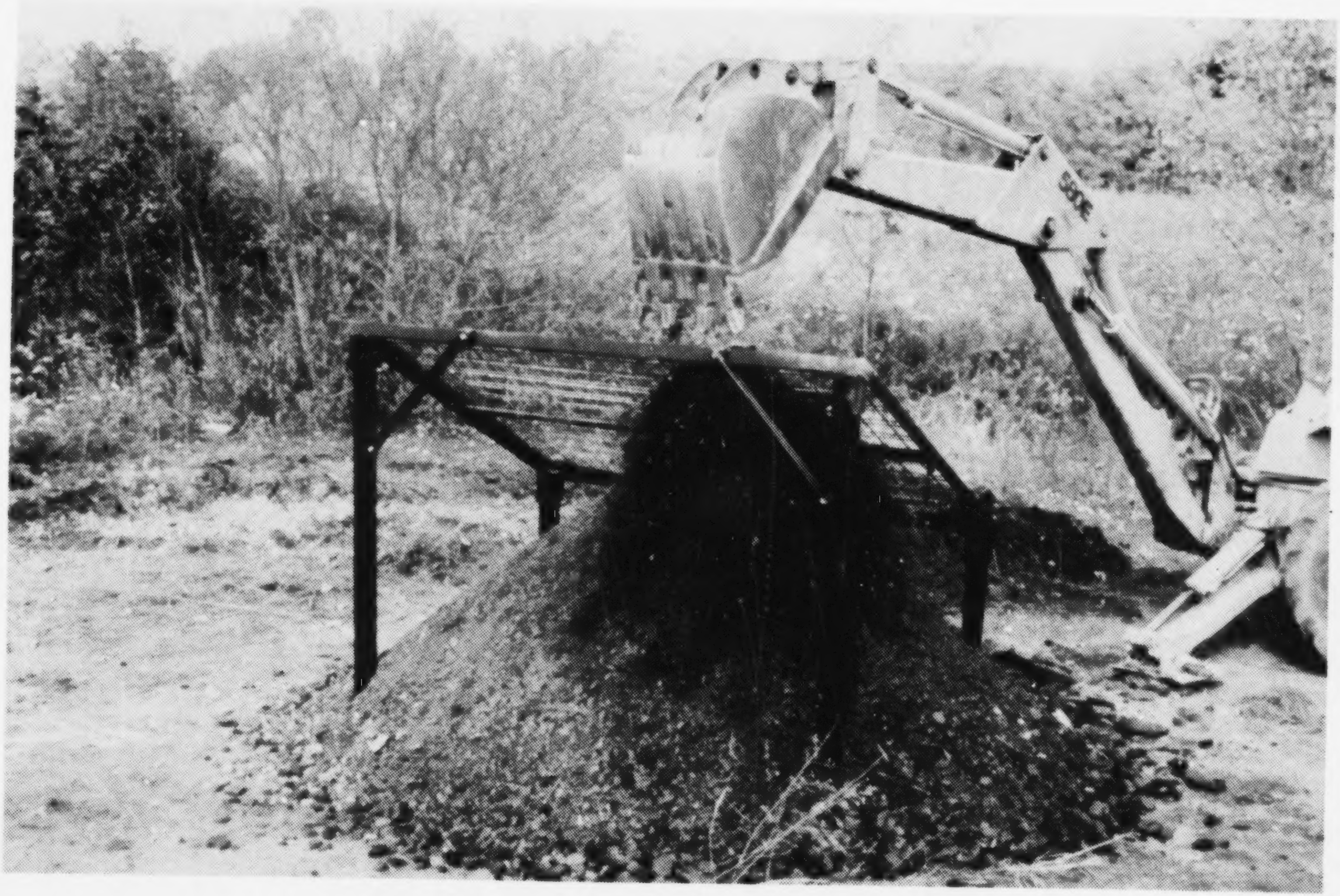

Figure 5.1. Screening operations.

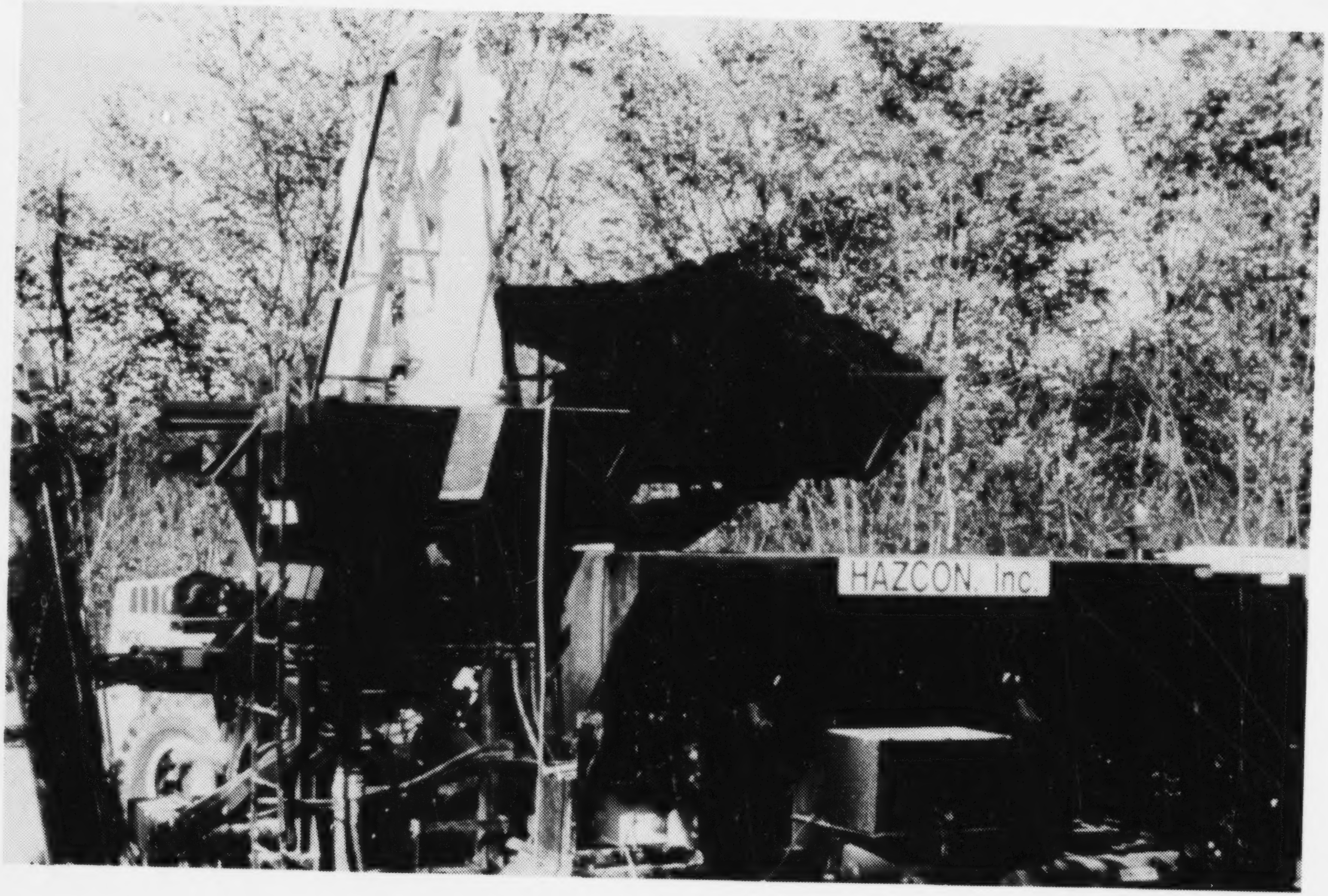

Figure 5.2. Soil feeding the HAZCON MFU.

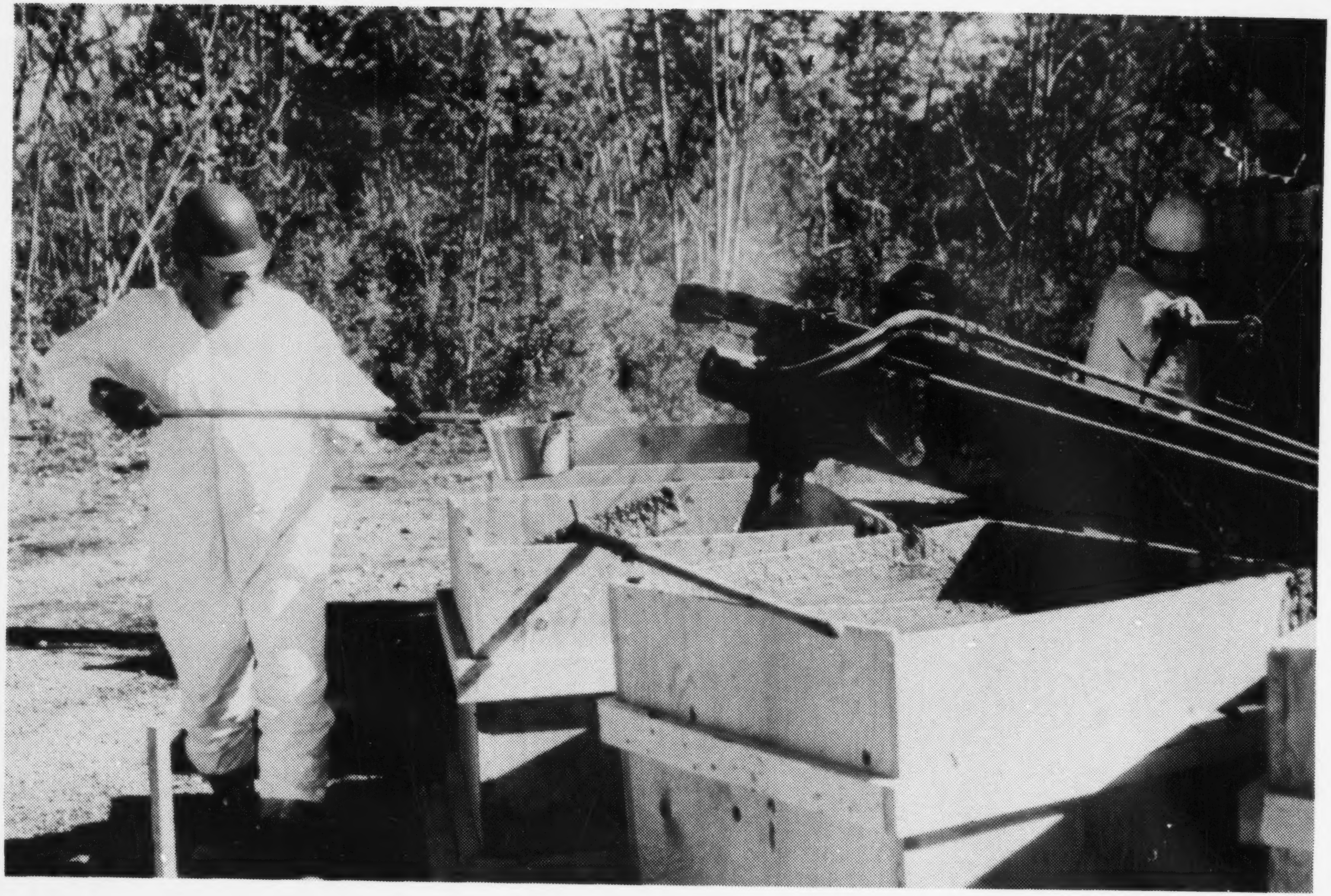

Figure 5.3. Slurry sampling from the MFU.

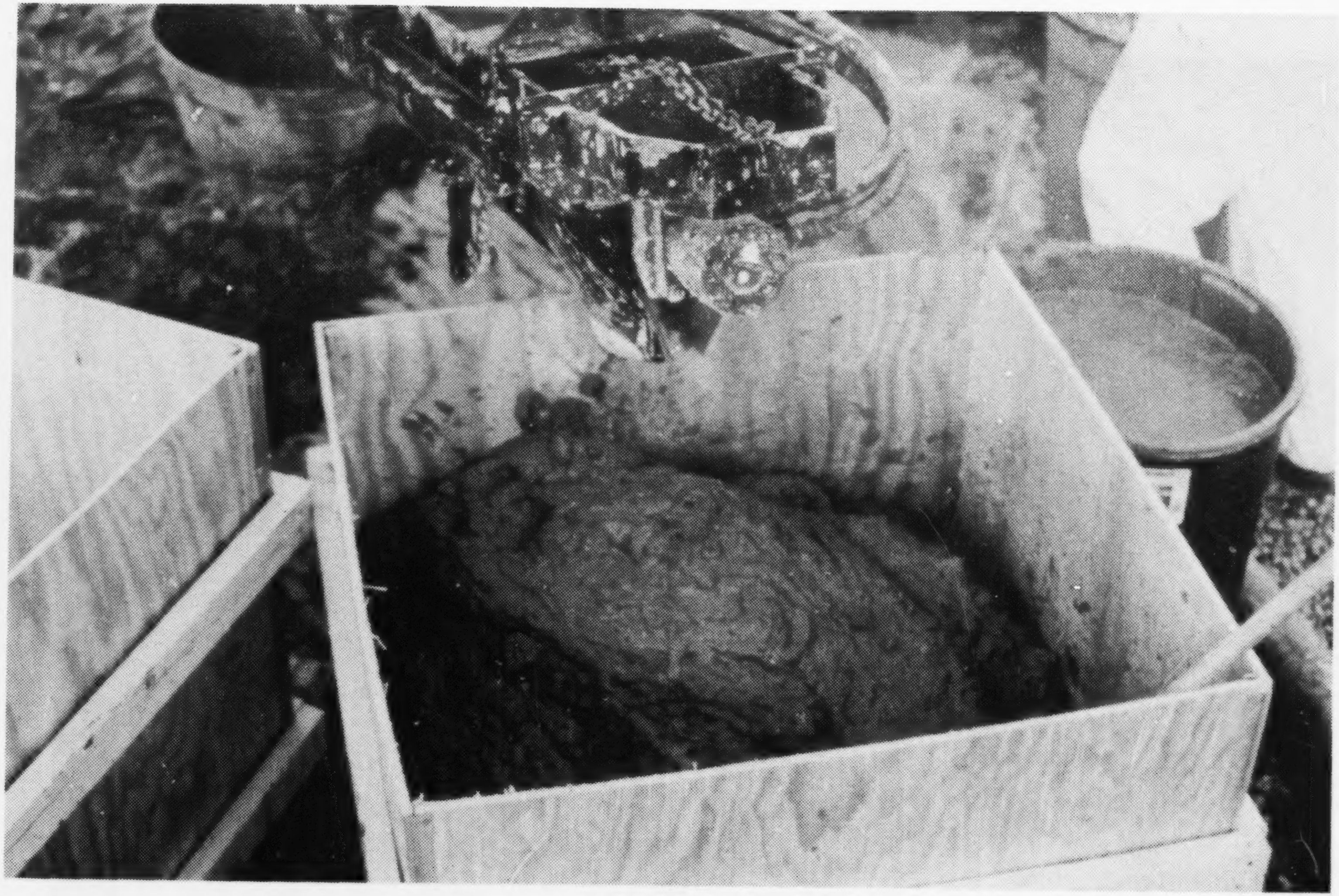

Figure 5.4. Slurry containment molds.

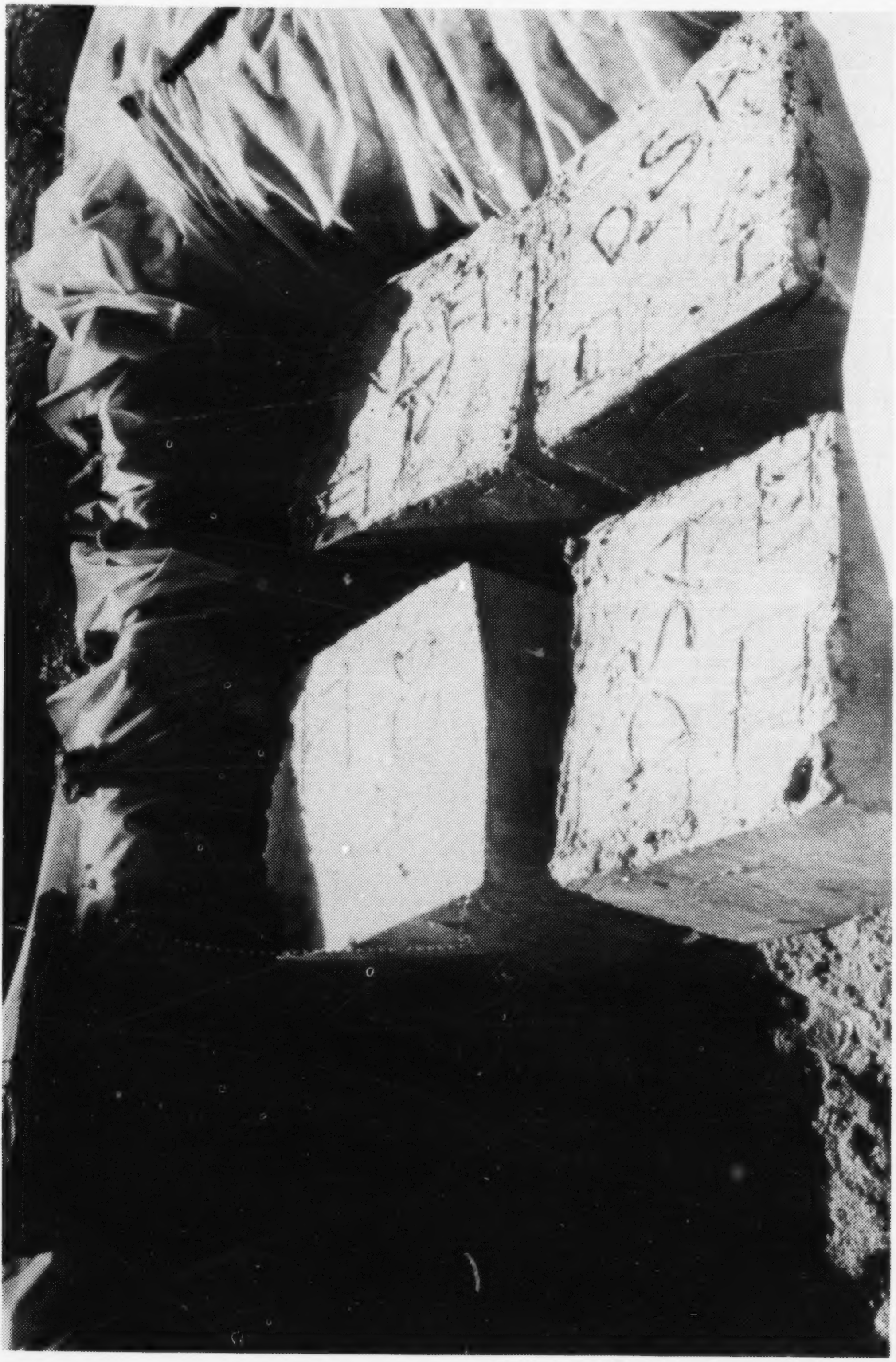

Figure 5.5. Burying the solidified blocks.

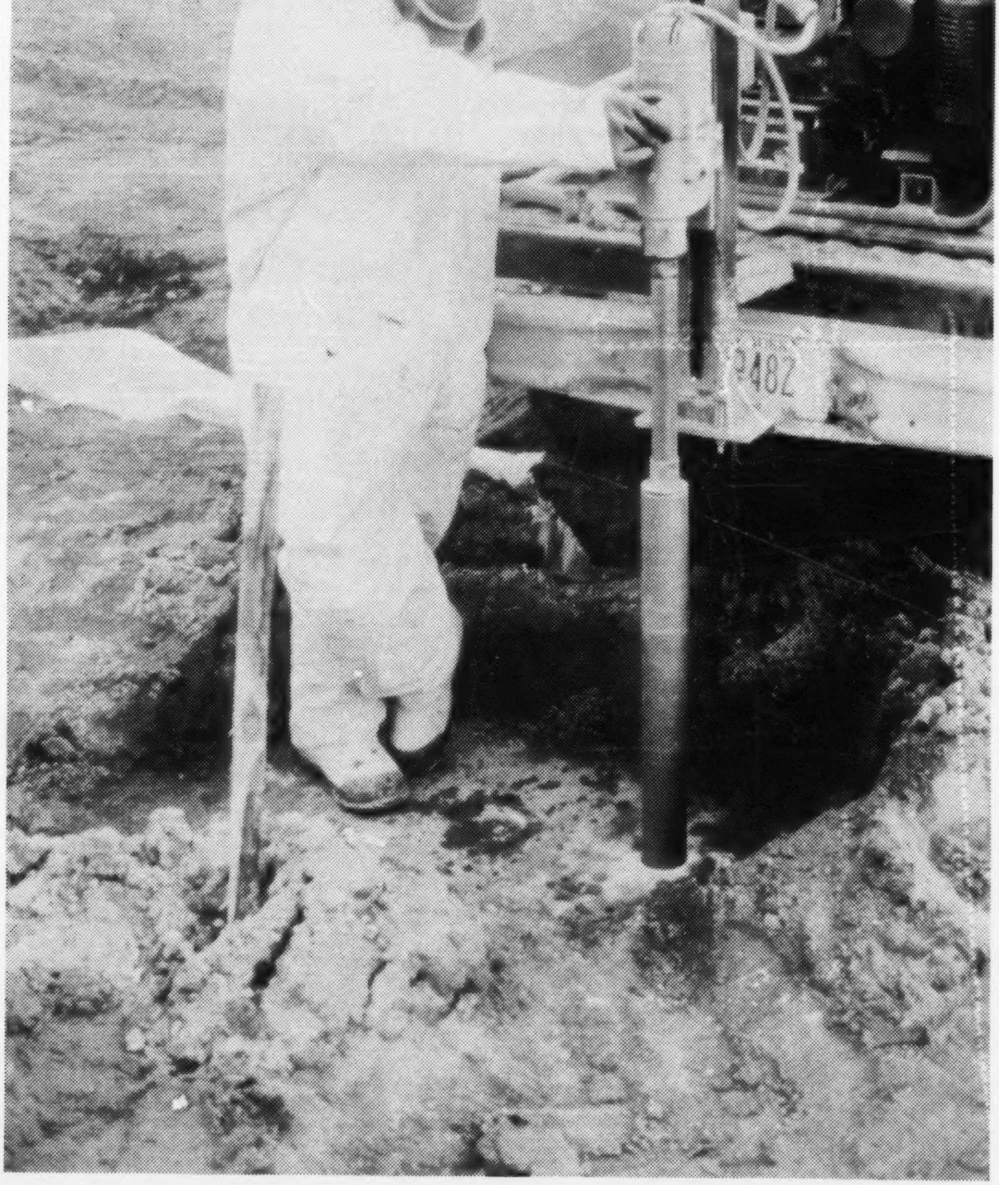

Figure 5.6. 28-day core sampling.

- Health and Safety related procedures, meetings, and concerns
- Chronology and summary of daily activities. This includes check-in and check-out of all personnel
- Sampling logs of Sampling and Analysis contractor
- Weather conditions
- List of visitors

5.2 OPERATING SUMMARY

Work at the Douglassville site commenced on October 5 and was completed on October 20, 1987. The Demonstration Tests occurred on October 13-16, 1987. The six working days before the actual tests involved site preparation and equipment setup, and the two working days after completion of the Demonstration Test were used to return the Douglassville site to the Pre-Demonstration Test condition. Highlights of the site preparation, operation, and posttreatment sampling are described below. A summary of the sampling program appears in Table 5.1.

5.2.1 SITE PREPARATION

October 5-9 -- During this week, prior to the Demonstration Test, the site was prepared. This included the following:

- Clear area of vegetation to Lagoon South and Drum Storage.
- Set up mobile equipment and tools to prepare site and assist Demonstration Test operations.
- Laying a gravel road to and preparing a 50x50 ft area at Lagoon South to provide an equipment decontamination area. Also provide an area for HAZCON to set up their equipment for the 25-cu-yd run on Lagoon South feedstock.
- Set up trailer and personnel sanitary facilities.
- Obtain diesel generator to power trailer and area lighting.
- Build an observation platform next to the trailer for visitors to witness the operations.
- Obtain water supply truck to be used for process water supply and equipment decontamination.
- Stake out exact areas to be sampled during Program.

TABLE 5.1. SUMMARY OF PROGRAM SAMPLING

Date	Sampling location	Test Blocks Produced	Test Blocks Sampled	Time, hrs Start/stop	Comments
10/13/87	DSA	4	1,3	1430/1815	Losing daylight - last block cancelled by consent of HAZCON/EPA. Toluene injected.
10/14/87	LAN	5	1,3,5	1136/1201	
10/14/87	FSA	5	1,3,5	1645/1703	
10/15/87	LFA	5	1,3,5	1059/1144	Toluene injected
10/15/87	PFA	4	1,2,3	1617/1817	Fifth block cancelled due to loss of daylight. Toluene injected.
10/16/87	LAS	5	SM2, LM1* LM 2A,* LM 2B,* LM 2C	1309/1645	Extended time run Produced three - 1 cu yd blocks plus two - 12 cu yd blocks

* Three samples taken from final 12 cu yd block poured.

5.2.2 OPERATIONS

October 12 -- Day 1 was utilized by Enviresponse for final site preparations before commencement of testing. HAZCON, Inc. and Radian Corporation, the Sampling and Analytical contractor, arrived and started their preparations. The tasks of the various parties included:

- Setting up of the HAZCON Mobile Field Blending Unit.
- Sampling equipment and documentation preparation by Radian.
- Providing electricity to the trailer and Radian's mobile field vehicle.
- Setting up the health and safety equipment, including the personnel decontamination area.
- Taking undisturbed soil samples at the Drum Storage Area.
- Initiating construction of wooden forms to contain treated soil slurry for the 25 cu yd run at Lagoon South.

October 13 -- The following highlights in chronological order the activities of Day 2 of the Demonstration Test.

0800-0900 Detailed Health and Safety meetings took place with all the on-site contractors.

0900-1200 Radian collected undisturbed (with Shelby tubes) soils from LAN, LFA, and PFA.

0930-1000 HAZCON made preparations for a preliminary 1 cu yd trial run to check out all aspects of their system from feeding soil to decontamination.

1030-1200 HAZCON preliminary test performed.

1200-1300 Grubbed at Drum Storage Area and checked for volatile organics with HNU meter.

1300-1400 Excavated and screened feedstock from DSA.

1430-1700 Started feed to HAZCON MFU. Feed screw jammed almost immediately. Problem was probably due to a buildup of dry soil in soil auger feedscrew that caked and displaced the auger. Chloranan feed line also ruptured. HAZCON unit was disconnected and flushed clear at decontamination area. Future runs added water at the auger through the top of the bin to facilitate the soil flow.

1715-1815 Restarted DSA 5 cu yd run. Soil feed screw jammed almost immediately, but it was flushed clean in 5 minutes. Chloranan feed lines ruptured four times. First product for sample block 1 at 1735 hours. Operations erratic after commencement. Samples taken while block 1 being poured. Operations at time of slurry samples unstable. Pouring of block 2 smooth. Pouring of block 3 was very erratic, as feed screw plugged again and Chloranan lines disconnected again. Samples taken from block 3. The final block for this run was No. 4, with the slurry feed quite dry at the start and quite wet near the end of filling. Toluene was added at a constant rate throughout the run at approximately 19 ml/min even though slurry production was variable.

1815 The run, based upon the agreement between EPA and HAZCON, was stopped before a fifth block could be poured due to the need for more feedstock and a lack of daylight. Time was still needed by HAZCON to decontaminate their equipment before total darkness.

October 14 -- The following highlights in chronological order Day 3 of the Demonstration Test.

0800 A short health and safety meeting was held.

0815-1000 HAZCON installed a new water pump for better control of water addition and fixed the Chloranan feed line.

0830-0930 Undisturbed soil samples taken at LAS and FSA.

0930-1030 Lagoon North contaminated soil excavated and screened.

1136 Started Demonstration Test on Lagoon North soil which is very black in appearance. First block took 6 minutes with slurry very thick. Some loss in Chloranan flow at the beginning of the block. Slurry sample taken at 1139 hrs. Feed hopper kept only partially full.

1142 Started slurry flow to mold 2, and it was very wet. After 2 minutes the process unit had to be shut down for one minute. After restart, the slurry was thick, then turned watery again.

1146 Started slurry flow to mold 3. Except for one brief stop, mold was filled with very wet cement slurry.

1152 Started slurry to mode 4. Consistency was judged by EI to be good relative to normal concrete consistency. Slurry flow stopped for one minute at 1154 hrs. Sampled at beginning of block. Restarted and consistency remained good.

1157 Started slurry to mold 5 and sampled immediately. Stopped at 1158 hrs for one minute, then completed block. Consistency ranged from watery to good.

1201 Test completed.

1500-1530 Excavated Filter Storage Area (sludge too sticky to screen). Cement and soil feed calibrated.

1645 Started filling mold 1 of FSA. Slurry consistency very thick. First sample taken. Slurry color quite black.

1649 Started filling mold 2. Slurry rate high. Slurry quite wet and grayish in color.

1652 Started filling mold 3. Slurry better consistency but still periods of being watery. Slurry sample taken. Color is gray. The wooden block frame partly failed, and some slurry was lost, less than 1 cu ft.

1656 Started filling mold 4. Slurry started very wet, but halfway through became thick, dry, and black in color.

1659-1703 Started filling mold 5. Slurry became wet almost immediately. Sample taken early in filling of mold.

October 15 -- The following highlights in chronological order Day 4 of the Demonstration Test.

0900-1000 Landfarm feedstock excavated and screened.

1028-1056 Calibration of soil, cement, Chloranan, and toluene feeds.

1059 Started filling of mold 1. Slurry started very dry but then was adjusted to a good consistency. Slurry sample then was taken. Toluene feed rate 18

	ml/min. Toluene feed lost for almost 30 seconds during filling of mold.
1105	Started filling of mold 2. Slurry started with good consistency. Production stopped at 1106 for 30 seconds. Slurry then ran very wet for 3 minutes. System ran out of cement and was shut down for 11 minutes. Test resumed with slurry starting very dry and then becoming of satisfactory consistency.
1120	Started filling of mold 3. Consistency of slurry started well and sample taken. After 3 1/2 minutes, slurry became so dry that water was added directly to the block. Production stopped.
1129	Started filling of mold 4. Consistency started well. After two minutes production stopped for almost 2 minutes so waste can be tamped down in bin. After 2 1/2 more minutes (1136) production stopped to wait for additional feedstock, which arrived at 1138 hrs. Production resumed.
1139-1144	Started filling of mold 5. Consistency of slurry was good throughout. Samples were taken.
1400-1500	Plant facility area feedstock was excavated and screened.
1617-1650	Started filling of mold 1. Toluene addition was made at 17 ml/min. Sample taken after 1 1/2 minutes. After 3 minutes, the auger was obstructed and unit stopped with only half of first block filled. HAZCON flushed unit out at decontamination area. Feedstock discarded - new feed potentially lower in organics obtained.
1802	Filling of mold 1 continued without further recalibration of processing unit.
1805	Started filling of mold 2. Sample taken. Operation smooth with good consistency of product.
1810	Started filling of mold 3. Production interrupted for 30 seconds due to problem in blending auger. Sample taken.
1817	Started filling of mold 4. Filled half of the mold and shut down, 2 minutes. There was a problem in soil feed. Fourth block completed. Due to time, fifth block cancelled by agreement of EPA and HAZCON.

October 16

0800-1300	Excavating and screening feed from Lagoon South. Excavation holes for treated slurry had been previously prepared, and a wooden containment mold had been installed in a different area of LAS. HAZCON relocated their equipment to the LAS decontamination area.
1154-1220	HAZCON calibrates equipment.
1309	Operations began for LAS feed.
1315	Slurry reached first block. Consistency good.
1320	Started filling of mold 2. Sample taken. Consistency good.
1325	Started filling of mold 3. Consistency good.
1330	Started filling first hole.
1333	Cement hopper refilled - no lost operation time.
1336	One minute interruption in operation. Second load of feedstock started.
1348	Sample taken.
1401	One minute interruption in operation waiting for feed. Third front-end loader feedstock started.
1414	Six minute interruption while cement hopper refilled.
1435	Cement hopper refilled.
1448	Filling of hole 1 complete. Block for DSA placed in its hole and covered with backfill and staked. Pipe moved to second hole.
1508	Operation resumes to 2nd hole.
1513	Operation interrupted for 7 minutes waiting for soil feedstock. Start fourth load of feed.
1525	Sample taken. Consistency of product good.
1536	Three minute interruption due to jamming of blending auger.
1550	Fifth load of waste soil started.
1624	Sixth load of waste soil started.

1625 Three minute interruption due to jamming of blending auger.

1635 Sample taken.

1645 Run completed. HAZCON and Radian cleaned and packed up to leave site.

October 19-20 -- All blocks from LAS, PFA, LFA, LAN, and FSA placed in excavations, backfilled with clean soil, and staked for identification. Site was then returned to Pre-Demonstration Test conditions.

5.2.3 POSTTREATMENT SAMPLING

Sampling of cured blocks commenced the week of November 16. A series of 3-in and 1.8-in cores were taken from the blocks to be consistent with the slurry feed samples. Core sampling started midday on 11/17/87 at LFA. Blocks 1, 5, and 3 were sampled in that order.

On November 18, LFA was completed, and sampling at LAS commenced, with the first large excavation hole. Sampling at Lagoon South continued next at the second large excavation hole where two sets of samples plus a duplicate were collected. On November 19, core sampling was done at the second large excavation; LAS sampling was conducted with block 2. Sampling at LAN on block 4 began on the afternoon of the 19th. Samples from block 1 were also taken. Work on November 20 commenced with the completion of sampling at LAN, block 5. Cores from the Plant Facility Area commenced with block 1. Sampling was then discontinued for the weekend. The weekend was very cold and windy causing some freezing of the wet clean soil backfill.

On Monday morning, November 23, sampling at the Plant Facility Area commenced with the completion of sampling of block 1. Blocks 2 and 3 were sampled and the drill rig was moved to the Drum Storage Area. Block 1 was sampled before darkness halted operations. On November 24 the DSA was completed and the final area, FSA, was started with block 5. All the blocks in FSA were "soft" and some difficulty was encountered in obtaining sufficiently large core pieces to perform the laboratory analyses, particularly for FSA-3. However, a full set of laboratory analyses on the cores from this block was possible.

5.3 PROBLEMS AND DEVIATIONS FROM DEMONSTRATION PLAN

This section describes changes in the Demonstration Test that have occurred since the approval of the Quality Assurance Project Plan and the final issue of the Demonstration Plan. Field operational problems are described.

5.3.1 FIELD OPERATION PROBLEMS

Major problems were not encountered during the Demonstration test. Two runs per day of the 5-cu-yd test areas were possible, although the hope for three-run capability proved not to be practical. Accumulation of minor unexpected difficulties extended the duration of each test. Some of these difficulties were as follows:

- o The shallow depth, 12 inches or less, of the contamination in all areas except LAN, required added time to collect the feedstock.
- o The soil feedstock jammed the feed auger on the HAZCON unit many times. On two occasions, this required the complete flushing of the process unit at the decontamination area, which resulted in up to 2-3 hours in delay.

As a result of these minor delays, the 25-cu-yd extended duration test was not performed until Friday, October 16. So although the entire Demonstration Test was completed in 5 days as planned, including mobilization and demobilization, the actual testing period spanned four days instead of three.

5.3.2 SAMPLING AND ANALYSIS CHANGES

Changes in the Sampling and Analysis program occurred in the field, based upon discussions with Radian Corporation and observations of the operation. These changes, primarily additions, are listed below with an explanation.

- o Access to the Filter Sludge Storage Area was very limited due to the inability of the filter cake to support the weight of the mechanical equipment. For this reason LAS material was used for the extended run instead of FSA. In addition, the feed for FSA was taken at the SE corner of the area, not in the area that the preliminary screening samples were taken. As a result of changing the feedstock, the HAZCON MFU for the 25-cu-yd run was relocated to the northwest edge of LAS instead of an area west of the filter cake.
- o All of the 25-cu-yd treated soil, except for the three 1-cu-yd blocks, was pumped into two excavations instead of three. Due to the practical convenience of constructing the forms to contain the slurry using standard size 4x8-ft sheeting, the excavations were larger than originally planned. Therefore, instead of three excavations of 9 cu yd each, only two were needed, each filled with 10-12 *cu yd of treated slurry. The third excavation*

hole prepared, the one furthest to the south, contains only the three 1-cu-yd blocks.

- The baseline laboratory formulations (without Chloranan) were performed in duplicate for two contaminated soil feedstocks, LAN and FSA, instead of the originally planned one, which although not defined, would have been FSA. Physical tests were performed after 9 and 28 days to conform to the field samples.

- The seven-day physical testing was performed over a variable time frame. This was mainly due to the fact that the samples were taken over a four-day period and they did not return to the laboratory until 8 days after the first samples (DSA) were taken. Unconfined compressive strength was performed after 8-10 days. The permeability tests were performed 2-12 weeks after collection. This was due to laboratory difficulties that had to be overcome.

- Untreated soil samples were taken by scoop from the front-end loaders used to transport the screened feedstock to the HAZCON unit. Shovels and triers were not necessary to obtain representative samples.

- Slurry samples were taken in a 1-liter stainless steel dipper. This was not clearly defined in the Demonstration Plan.

- Constant head permeability measurements were made on undisturbed soil collected in Shelby tubes, not on remolded samples, as specified by ASTM D2434.

- The toluene injection rate was about 25-50% higher than planned. This was due to lower process feed rates being used than anticipated, and to the fact that the minimum pumping rate for the toluene pump was 17-18 ml/min, which is too high for the reduced feed rate.

- Six EP Tox leaching tests were performed on untreated Filter Cake and Lagoon North feedstocks for priority pollutant metals only. This addition provides some comparative data on EP Tox and TCLP for metals.

- Slurry samples were not always taken at the 1/10, 5/10, and 9/10 time frames of a run. This would have been equivalent to blocks 1, 3, and 5. Due to some of the minor difficulties in operation that

HAZCON encountered, this had to be adjusted for the Drum Storage Area (blocks 1, 3, 4 - no block 5), Plant Facility Area (blocks 1, 2, and 3), and Lagoon North (blocks 1, 4, and 5). The 28-day samples were taken from appropriate blocks to conform with the slurry samples.

- Some practical adjustments were made to the ANS 16.1 multiple extraction leaching procedure to reduce the complexity and costs and be more practical for use on hazardous wastes. The time frames for leaching were reduced to 5 intervals over a 28-day period as compared to the nuclear industry test of 10 time frames over an 89-day period. They were conducted at 1, 3, 7, 14, and 28 days. In addition, the container rinses, which are expected to be clean, were saved, but not analyzed. This leaching procedure was developed for testing of low radioactive level nuclear material and there is no definitive criteria in its application to hazardous wastes. This is based upon verbal contact with the procedure developers at Oak Ridge National Laboratory.

- The quality of No. 1 Portland cement was checked by measuring its compressive strength after 7 and 28 days, not by chemical analysis as previously stated. ASTM C150-85 was used as a basis.

- The process water was also added to the analyses performed. The water was analyzed for pH, TOC, suspended and dissolved solids, and standard water chemistry anions and cations. This analysis was added so that all the feed streams to the process, except HAZCON's proprietary additive, would be defined.

- Screening of the FSA feedstock to remove material greater than 3 inches was not possible due to the stickiness of the feedstock. It was not expected to encounter any rocks or large objects in this feed. Feed problems due to oversized material were not encountered.

- Because the field schedule made it impractical, soil pH was measured at Radian's laboratory, not at Douglassville as originally intended.

- Unconfined compressive strength tests were performed after the weathering tests, which is a program addition.

- Additional deviations from the approved QAPP are described in Radian Corporation's report in Appendix B, pages 22-23.

5.4 MATERIAL BALANCE

Six test runs were performed using contaminated soil feed from six plant site locations. The first five tests, DSA, LAN, FSA, LFA, and PFA, fed sufficient soil to produce approximately 5 cu yd of slurry products. These were fed to 1-cu yd wooden molds to cure for a time period of 48-96 hours, sufficient time so that they could be unmolded, moved, and buried. The sixth feed stock, from LAS, produced approximately 22 cu yd (original intent 25-30 cu yd) to test longer-term operability of the HAZCON MFU. The parameters and material balance for each test are shown in Table 5.2. The operating rates were taken from HAZCON's Calibration and Monitoring Work Sheets, copies of which are included in Appendix A.

For LFA, PFA, and DSA one front-end loader load (bucket filled level to the rim is ~ 2 1/4 cu yd) of soil plus cement, water, and Chloranan produced 3 1/2 to 4 cu yd of slurry mix. For LAN and FSA, one soil load was sufficient to fill five slurry molds. Although loose soil from the screening operation was used, with a bulk density less than the undisturbed or treated soil sample values reported in Section 6.0, the volume of treated slurry would be expected to more than double that of the loose soil. Therefore, producing 4.0 to 5.0 cu yd of slurry appears proper. In addition, the number of blocks produced tends to agree with the total weight of the four feeds. Exact volume measurements of each cube was not performed. However, most of the molds (39" x 39" x 32") were filled to about 2-4 inches from the top, which is a volume of approximately 0.95 cu yd.

TABLE 5.2. SUMMARY OF HAZCON MFU OPERATING CONDITIONS

	DAS	LAN	FSA	LFA	PFA	LAS
Soil Feed, lb/min (b)	300	210	234	224	216	178
Cement, lb/min	306	212	240	228	220	183
Chloranan, lb/min	28.3	16.7	12.2	20.0	17.1	21.1
Water, lb/min	114	88	133	79	81	98
Total Feed Addition, lb/min	748	527	619	551	534	480
Total Soil, lb	4765	4478	4308	6570	4891	19385
Total Cement, lb	4860	4521	4418	6688	4982	19928
Total Chloranan, lb	450	360	225	585	387	2295
Total Water, lb	1810	1890	2450	2316	1832	10659
Total Weight, lb	11885	11249	11401	16159	12092	52267(d)
Bulk Density, lb/cu ft^3 (slurry core)	122	100	94	115	129	106
Total Volume, cu yd (d)	3.6	4.2	4.5	5.2	3.5	18.3
Cement/Soil Ratio	1.02	1.01	1.03	1.02	1.02	1.03
Chloranan/Soil Ratio	0.094	0.080	0.052	0.089	0.079	0.119
Water/Soil Ratio	0.38	0.42	0.57	0.35	0.38	0.55
Soil-to-Total Feed Ratio	0.40	0.40	0.38	0.41	0.40	0.37
Number of 1-cu-yd blocks (c)	4	5	5	5	<4	--
Operating Time, minutes[(a)] (based upon chronology)	15.9	21.5	18.4	29.3	22.6	170

Notes:

(a) A comparison of operating time from the chronology versus time to process total cement and Chloranan at measured rates agree for the five 5-cu yd test. For LAS, the chronology indicated that the total operating time was ~ 170 minutes. On this basis, the total cement and soil consumption, if at a 1:1 ratio, is low by about 20%. If the soil calibration rate held then the cement rate tailed off about 35%. For the Chloranan, if the run time was 170 minutes, then the average feed rate was 13.5 lbs/min with a Chloranan to soil feed ratio, assuming the soil feed was maintained, of 0.076 by wt.

(b) Quantity of soil is determined by calibration before the run started and its ratio to the cement during calibration. Cement is measured through a bag counter. Chloranan is measured by level change in a tank. Water is measured by flow totalizer plus supplementary water by tank level change.

(c) The 1-cu-yd molds were filled to within 2-4 inches of the top, which is about 0.95 cu yds.

(d) Based upon HAZCON Monitoring Work Sheets

SECTION 6

SAMPLING AND ANALYTICAL PROGRAM

6.1 SAMPLING LOCATIONS

Soil feedstocks for the Demonstration Test were drawn from six areas. The sources of the contamination were the result of different plant operations. The locations, using Figure 4.2 as a reference, are as follows:

Lagoon North (LAN) - 380 feet NNE of MW 11-1
Lagoon South (LAS) - 100 feet SSE of MW 3-2
Plant Facility (PFA) - 60 feet N of MW 10-2
Filter Cake Storage (FSA) - SE corner about 50 ft west of N-S road
Drum Storage (DSA) - 60 feet SSE of incinerator stack
Landfarm (LFA)- 60 feet east of MW 11-1

Sampling locations were based upon results from the RI/FS report performed by NUS Corp.

The lagoons were for many years sludge storage areas from the waste oil reprocessing plant operations. Most of the organics were washed away in the floods of 1970 and 1972, and the lagoons were subsequently backfilled with clean soil. The contamination at the processing plant and drum storage areas is the result of spills. The filter sludge area contains a piled oil sludge filter cake. Oily sludge from the oil reprocessing operations was tilled into the soil from 1979 to 1981 producing the landfarm area.

The screening samples, as discussed in section 4.2.6, helped define the feedstock locations. At Lagoon North, the highly contaminated soils were 1 to 3 feet below the surface. At the other five locations, the contamination was at the surface. The depth to which the feed was excavated was closely monitored to minimize the use of relatively clean soil.

6.2 SAMPLING SCHEDULE

The Demonstration Test Plan [3] called for soil samples to be taken during three time frames. These were:

Pretreatment - Samples of feedstock were taken just prior to feeding the holding bin on the HAZCON MFU

Treated Slurry - Treated slurry samples were taken at the outlet of the processing unit, the blending auger. Laboratory analyses were scheduled to be initiated after approximately seven days of curing. Due to the long time required to perform the permeability analyses, many of these tests occurred after 28 days.

Solidified Soil - The solidified soil blocks, returned to their excavation sites, were sampled a little more than 28 days after treatment.

Samples from the solidified blocks and the surrounding soil will be taken periodically to monitor the solidified block integrity over a five-year time span. All the pretreatment and treated slurry samples were collected at the time of testing, in October 1987. Solidified soil samples were bored out of the solidified blocks during the third week in November, 1987. The initial long-term samples will be taken in July of 1988.

6.3 SAMPLE RECOVERY PROCEDURES

The Sampling and Analysis contractor (S&A), Radian Corporation, collected samples of the following: contaminated soil prior to treatment, treated slurry as it exited the mobile processing unit, and 28-day-old solidified treated soil (see Figure 6.1).

6.3.1 PRETREATMENT

Minimally disturbed contaminated soil samples were collected for bulk density and permeability measurements. The S&A sampling crew went to the area designated for a given test before excavation started and obtained the scheduled number of cores using a 3-inch Shelby tube. The depth of the cores depended upon the estimated depth of contamination in the area being sampled. The cores were sealed by covering the ends of the Shelby tube with aluminum foil and sealed with tape. If needed to assure core integrity during shipping, inert material (plastic packing foam or clean sand) was added to the portions of the tube not filled with the core.

Contaminated soils for the other tests were collected either from a composite pile at the excavation site or from the earth moving equipment, as it was transferred to the mobile processing unit. Scoops were used to obtain the samples. Individual soil portions were taken from different parts of the composite pile or from the material in the earth moving equipment so that several parts of the source contaminated soil were represented. The individual portions that were obtained each time the scoop was dipped into the soil were placed into a stainless steel container.

Once all individual portions were collected, the contents of the container were mixed by hand and the mixture transferred to individual labeled sample jars.

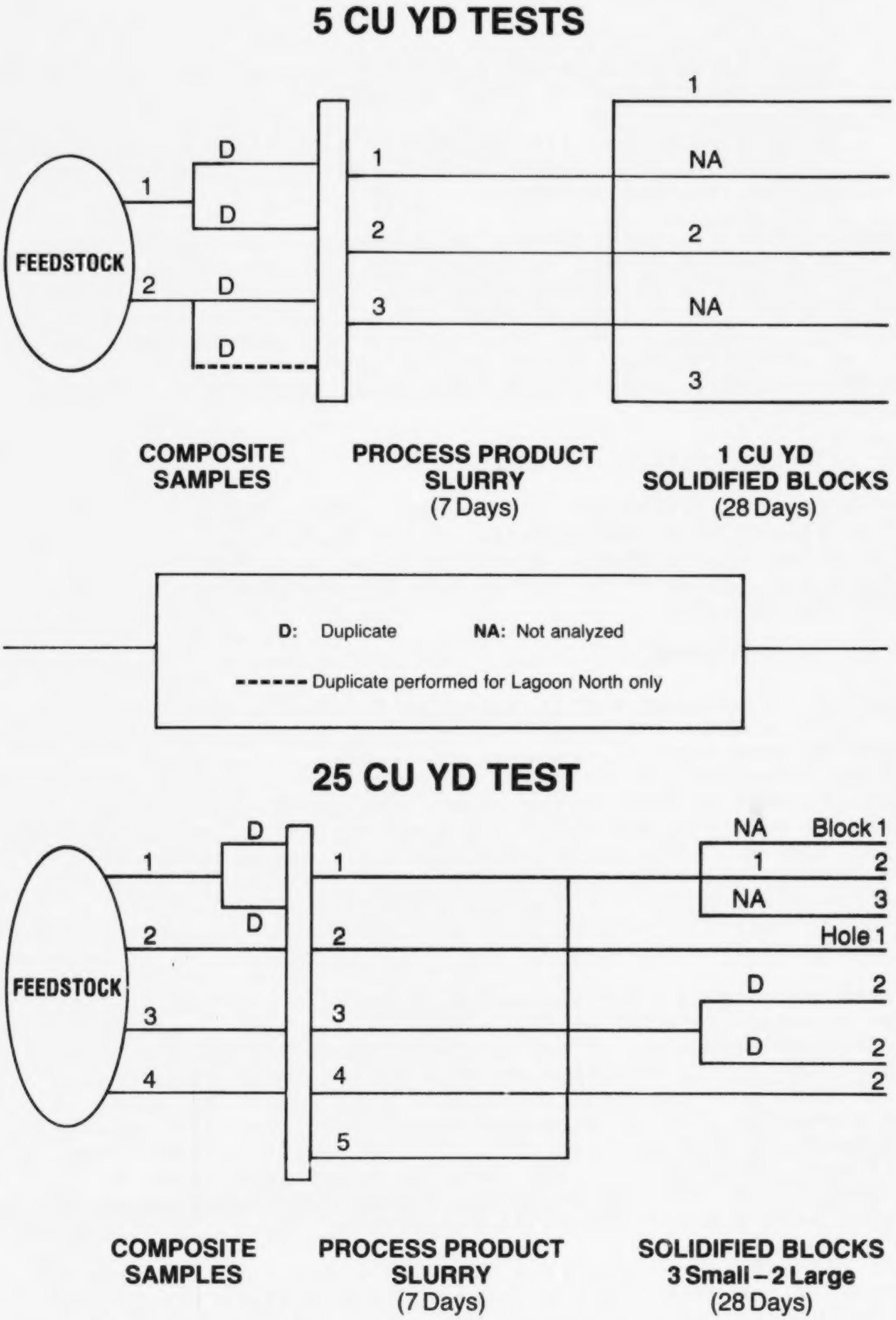
5 CU YD TESTS
FEEDSTOCK
1
2
D
D
D
D
1
2
3
1
NA
2
NA
3
COMPOSITE SAMPLES
PROCESS PRODUCT SLURRY (7 Days)
1 CU YD SOLIDIFIED BLOCKS (28 Days)
D: Duplicate
NA: Not analyzed
------ Duplicate performed for Lagoon North only
25 CU YD TEST
FEEDSTOCK
1
2
3
4
D
D
1
2
3
4
5
NA
Block 1
1
2
NA
3
Hole 1
D
2
D
2
2
COMPOSITE SAMPLES
PROCESS PRODUCT SLURRY (7 Days)
SOLIDIFIED BLOCKS 3 Small – 2 Large (28 Days)

Figure 6.1. Sampling scheme.

6.3.2 TREATED SLURRY

The treated slurry was collected at the discharge point of the HAZCON mobile processing unit. Grab samples were taken during the beginning, mid-portion, and end of a treatment run. The grab samples were taken using a stainless steel dipper. The pan part of the dipper had a capacity of 1000 mL, and the handle was approximately 3 feet long. The dipper had the advantage that the person collecting the sample was farther from the waste stream. Samples were packed into cylindrical cardboard molds immediately after they were collected. The cardboard cylinders were placed in individual sealable plastic bags. The glass jars were sealed by screwing on a Teflon-lined lid. A containment vessel (shallow pan) was required at the point the treated slurry was transferred from the dipper to the sample containers.

6.3.3 SOLIDIFIED SOIL

After approximately 28 days, samples of solidified soil were collected using a rotary rig with core barrel. The outside diameters for the cores were 7 cm for unconfined compressive strength and permeability tests and 4.5 cm for wet/dry, freeze/thaw and leaching tests. Cores were removed from the core barrel and sealed in aluminum foil to prevent moisture loss. Packing and shipping methods were chosen to minimize disturbance to the cores.

Cores were removed from the solidified blocks in a pattern designed to obtain solidified material that was representive of each block.

6.4 ANALYTICAL PROCEDURES

Soil samples were collected before treatment and after processing. Processed soil samples were analyzed both after approximately 9-12 days of curing and after 28+ days. Significant changes in treated material were not anticipated after four weeks.

Samples were taken to directly relate the feedstock properties with both the HAZCON process unit product slurry and the corresponding buried posttreatment blocks. The criteria for when and how the samples were to be taken is shown in Figure 6.1 and described in Sections 6.4.1 through 6.4.4 below.

6.4.1 BASE CASE

- o Clean soil backfill plus cement formulations, without Chloranan, were prepared in triplicate in the laboratory and many of the physical properties were checked (moisture, bulk density, compressive strength, and permeability), as a baseline against the results from the contaminated soil tests. These tests were performed nominally after 7 and 28+ days. Only one permeability on each formulation was performed after 28 days.

- The same as above except filter cake was used instead of clean soil.

- The same as above except sludge from Lagoon North was used.

- Samples of clean soil, cement, and water were taken for analyses. The clean soil was analyzed for TOC, PCBs, and lead. The cement was checked for compressive strength after 7 and 28 days to confirm that it was a typical No. 1 Portland cement. The water was analyzed for pH, TOC, suspended solids, and standard water chemistry anions and cations.

6.4.2 PRETREATMENT SOIL

- Two composite soil samples were prepared for each of the five 5-cu-yd feedstocks. The composites were prepared by taking soil scoops from twelve locations within the feed pile.

- The first soil composite was mixed and split into three parts, two for analysis and one held in reserve. The second soil composite, taken completely independent of the first, was analyzed as follows:

    - For Lagoon North, the composite was split into two parts. One part was analyzed completely and the second part for key component properties such as oil and grease, moisture, bulk density, pH, and lead content.

    - For the three feedstocks spiked with toluene at the mixing auger, laboratory spiking was performed, equal to the concentration level measured in the 7-day treated samples, before running the TCLP test.

    - For the other four areas producing 5 cu yd of treated soil, the second composite was not divided and was analyzed for only the key component properties.

- Four composite feed samples were taken at Lagoon South over the approximate three hour duration of the test. One of the composite feeds was divided into two parts with the second part analyzed for the key component properties only.

6.4.3 SLURRY SAMPLES (NOMINAL 7 DAYS)

- For the 5 cu yd tests, three separate sample sets were taken. The time frames targeted were approximately a tenth, a half, and nine tenths into the total run time. However, for LAN, samples were taken for slurry producing blocks 1, 4, and 5; DSA blocks 1 and 3; and PFA blocks 1, 2, and 3.

- For the 25 cu yd test, four sets of samples were taken over the three hour operating time frame. A duplicate sample set was taken during the second sampling period and was held in reserve.

6.4.4 POSTTREATMENT SAMPLES (28 DAYS)

- For the 5 cu yd tests the treated material was poured into five 1-cu yd molds, which after partial curing were buried in the excavation. Samples were taken to conform to the blocks from which the slurry samples were taken.

- For the 25 cu yd extended run test, the first three cu yds were fed into 1 cu yd molds and the remaining slurry into two 12 cu yd excavation pits. Sample sets were taken from the second 1-cu-yd block, plus one from the first and two from the second 12-cu-yd blocks (see Figure 5.1). A duplicate sample set was taken from the first sample of the second large block and held in reserve.

The tests, with analytical procedures performed for each pretreatment sample, are shown in Table 6.1. Seven-day posttreatment sample analyses are defined in Table 6.2, and the 28+ day posttreatment analyses are defined in Table 6.3.

Due to the anticipated low level of contaminants (particularly volatile organics) in the soil, toluene was injected into three of the five 1 cu yd feedstocks. The injection of 125 ppm toluene, which is typical of total volatile concentration found at Superfund sites, was added to facilitate volatiles measurement in the leachates from the three low-contaminant feedstocks, DSA, PFA, and LFA. The intent of this injection was to have one volatile organic that could be readily followed from untreated soil to treated soil to leachates (of untreated and treated soils). The minimum detection limits for the compounds being analyzed in soil and water are provided in Table 6.4. In many samples, due to the relative concentrations of the contaminants, higher detection limits were used.

All samples were carefully taken and kept in sealed containers at a reduced temperature to prevent loss of volatiles, particularly when toluene was injected.

TABLE 6.1 PRETREATMENT ANALYSES

Test Type	Procedure[b]
Grain Size	ASTM D422-63 (reapproved 1972)
pH	SW 846-9045
Moisture	ASTM D2216-80
Bulk Density	American Society of Agronomy - Methods of Soil Analysis, p.375
Oil and Grease	Standard Method 503D - American Public Health Association
Total Organic Carbon	Walkley-Black or combustion alternative
Priority Pollutant Metals (Sb, As, Be, Cd, Cr, Cu, Pb, Hg, Ni, Se, Ag, Th, Zn)	Digestion and Atomic Absorption or Inductive Coupled Plasma Atomic Emission Spectroscopy - SW-846; Digestion - SW-3050, SW-7471; Analysis (ICPAES) - SW-6010, (AA) SW-7060, SW-7421, SW-7740, SW-7841, (AA-Mercury) SW-7471
Total PCBs in Soil	SW846, Method 8080
Permeability	Constant Head - ASTM D-2434-68 (reapproved 1974)
Leaching - PCBs, Priority Pollutant Metals, VOC, BNA, and Oil and Grease in leachate	EP TCLP - Federal Register 11/7/86, Vol. 51, No. 216, Appendix 1, part 268; EPA 608 Metals - same as above VOC - SW-8240; BNA SW-8270 Oil & Grease - APHA SM-503D
Selected Volatile Organics - Soil	SW846, Method 5030, 8240
Selected Base Neutral/Acid Extractable Organics	SW846, Method 3540, 8270
Microstructural Examination(a)	X-ray Diffraction and Scanning Electron Microscope

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(a) One sample only from each location.
(b) A brief description of each procedure is provided in Sections 6.5 and 6.6.

TABLE 6.2 POSTTREATMENT ANALYSES - SEVEN DAYS

Test Type	Procedure
Bulk Density	Test Methods for Solid Waste Characterization (TMSWC) - Section 2
Moisture	TMSWC - Section 4
Unconfined Compressive Strength	ASTM D-2166
Permeability	TMSWC - Section 13
Leaching PCBs, Volatiles, Toluene, BNA, and Oil and Grease	TCLP - Federal Register, 11/7/86, Vol.51, No.216, Appendix 1, Part 268; PCB - EPA-608 VOC - Method SW-8240 BNA - Method SW-8270; Oil and Grease APHA SM-502
Toluene in Soil	SW846 Method 8240

TABLE 6.3 POSTTREATMENT ANALYSES - 28 DAYS

Test Type	Procedure(e)
Moisture	Test Methods for Solidified Waste Characterization (TMSWC) Section 4
Bulk Density	TMSWC - Section 2
Unconfined Compressive Strength(c)	ASTM D-2166
Wet/Dry Weathering Test(c)	TMSWC - Section 12
Freeze/Thaw Weathering Test(c)	TMSWC - Section 11
Permeability (Falling Head)	TMSWC - Section 13
Leaching - PCBs, VOC, Toluene, BNAs, Oil and Grease	EP TCLP - Fed Reg., 11/7/86, Vol. 51, No. 216, Appendix 1, Part 268 + EPA 608-PCB; VOC - SW846 Method 8240; BNA Method 8270; Oil & Grease - APHA SM-502
Priority Pollutant Metals(a) (Pb, Cr, Ni, Zn, Cu, Cd)	Atomic Absorption and Inductively Coupled Plasma Atomic Emission Spectroscopy - SW-846 Methods SW-7060, SW-7421, SW-6010
	MCC-1P-Static Leach Test(b) - Matrix B, 40°C (Materials Characterization Center) - metals same as for TCLP

(continued)

TABLE 6.3 (continued)

Test Type	Procedure
	(b)ANS 16.1 - Multiple Extraction (American Nuclear Society 28-day modification) + EPA 608; Metals same as for TCLP
Total Oil & Grease in soil(d)	SM-503D-American Public Health Association
Toluene in soil (spiked samples)	SW846 Method 8240
Micro Scale Examination	X-ray diffraction and scanning electron microscopy
Cement Chemical/Physical Analyses	Strength measurements at 7 and 28 days

(a) No other metals were detected in pretreatment phases in significant quantities.

(b) One sample from each treated feedstock except DSA and LFA. Total of four leach tests for both MCC-1P and ANS 16.1.

(c) Using one sample from each feedstock, additional unconfined compressive strength tests were performed on the product remaining after the Wet/Dry and Freeze/Thaw Weathering Tests are completed.

(d) Two samples of backfill soil were analyzed for organic contaminants and priority pollutant metals.

(e) A brief description of each procedure is provided in Sections 6.5 and 6.6.

TABLE 6.4. MINIMUM DETECTION LIMITS

Chemical	In Water ug/liter	In Soil ppm by wt.
Priority Pollutant Metals		
Arsenic	4	< 50
Antimony	6	<100
Beryllium	1	< 0.5
Cadmium	3	5
Chromium	9	< 20
Copper	10	< 50
Lead	50	5
Mercury	0.2	5
Nickel	20	< 5
Selenium	2	50
Silver	10	5
Thallium	3	2.5
Zinc	6	< 50
Base Neutral/Acid Extractables		
Naphthalene	20	0.7
Fluorene	20	0.7
Fluoranthene	20	0.7
Pyrene	20	0.7
Bis(2-ethylhexyl) phthalate	20	0.7
Benzo-(k)-fluoranthene	20	0.7
Phenols	20	0.7
Volatiles-Organics		
Toluene	10	0.010
Benzene	10	0.010
Xylenes	10	0.010
Ethylbenzene	10	0.010
Tetrachloroethene	10	0.010
Trichloroethene	10	0.010
1,2-Dichloroethane	10	0.010
Carbon Tetrachloride	10	0.010
PCBs		
Aroclor 1260	1	0.040
Aroclor 1248	0.5	0.020

The purposes of the various pretreatment analyses are many. Grain size, pH, moisture, and bulk density define basic soil characteristics. Bulk density will define volume changes that occur to the soil during remediations. Oil and grease and total organic carbon are both measures of organics in the soil being treated that may impact on the stabilization/solidification process. In many technologies that are cement-based, organics inhibit the cement hydration reactions. Analyses for priority pollutant metals, PCBs, base neutral/acid extractables, and volatile organics in all the samples determine the contaminant levels of the soils being processed. The permeability and leaching tests provide baseline data on physical mechanisms such as contaminant mobility that should change dramatically with the soil treatment.

Posttreatment analyses characterize the treated soil. Moisture and bulk density analyses provide treated soil property information. The unconfined compressive strength (UCS) provides a measure of the uniformity of the product mix and the impact of oil and grease concentrations. High strengths indicate a more uniform soil and additive mix (due to the cement microstructure produced) and provide maximum benefits, such as durability. An inability to tie up the organics, (organics exist at concentrations of up to 25% by weight), would significantly reduce unconfined compressive strength. Other factors that affect UCS are cement-to-soil ratio, mixing efficiency, soil characteristics, other pozzolans, and moisture quantity. (These parameters were not varied to check their impact for this Program.) The x-ray diffraction and scanning electron microscopic examinations provide additional information on the integrity of the solidified soil, and may provide qualitative information on the potential durability of the soil blocks. The wet/dry and freeze/thaw weathering tests provide an indication of the life expectancy of the solidified material when under repeated extremes in cyclic exposure (12) to moisture and temperature cycles.

Two special leach tests were included for the 28-day treated soil that simulate the material as it would exist in a solidified mass; they were the MCC-1P (Static Leach Test) and the ANS 16.1 (Multiple Extraction Leach Test). Both of these tests were developed for use with low-level radioactive wastes for the nuclear industry, but have been modified for use with hazardous wastes. Since the standard TCLP procedure requires grinding of the solidified mass, it may have represented a more severe leaching condition.

6.4.5 RANGE OF TESTING

The range of contaminant testing on which the HAZCON technology was demonstrated were limited to the contamination and soil characteristics existing at the Douglassville site.

The primary variables investigated in the Demonstration Test were:

- Particle size, moisture content, and contaminant levels in the soil from the six locations
- Grease and oil content
- Volatiles and BNAs including 3 feedstocks where 125 ppm by wt. toluene was added
- PCBs
- Lead

6.5 PHYSICAL TESTS

The physical tests described below were used to analyze the soil and leachate samples during this SITE Program.

ASTM D 422-63: Grain Size Analysis

This method covers the quantitative determination of the distribution of particle sizes in soils. The distribution of particle sizes larger than 75 um (retained on the No. 200 sieve) is determined by sieving, while the distribution of particle sizes smaller than 75 um is determined by a sedimentation process using a hydrometer to secure the necessary data.

SW846 Method 9045: Soil pH

The pH of a sample was determined electrometrically using either a glass electrode in combination with a reference potential or a combination electrode. In soil samples, pH will be determined by preparing a slurry using equal volumes of soil and deionized water and measuring the pH of the decanted liquid.

ASTM D 2216-80: Water Content (Moisture)

ASTM Method D 2216 was used to determine the water content of untreated soil samples. Moisture is determined by measuring the mass of water removed by drying the sample to a constant mass at 110 $\pm 5^{o}$C.

TMSWC-4: Water Content (Moisture) - Solid Cores

The sample is ground to pass an ASTM No. 10 sieve. The mass of the sample is measured before and after drying in an oven maintained at 60 $\pm 3^{o}$C. The dry weight must be a constant weight (mass change of less than 0.03 g in 4 hours). The wet sample mass is divided into the difference of the wet sample mass minus the dry sample mass.

Bulk Density

Bulk density was determined using the method described in Methods of Soil Analysis, American Society of Agronomy, 1965. The mass of the samples were calculated by difference using a top loading balance. The dimensions of the specimen (cube or cylinder) are measured using a 30-cm ruler having a precision of ±1 mm. The bulk density is calculated by dividing the volume into the mass.

APHA 503D: Oil and Grease

Method 503D is a modification of the Soxhlet extraction method, which is suitable for sludges. Magnesium sulfate monohydrate is combined with the sludge to remove water (as $MgSO_4 \times 7H_2O$). After drying, the oil and grease is extracted in a Soxhlet apparatus with trichlorofluoromethane and measured gravimetrically.

Total Organic Carbon

Inorganic carbon is removed by sulfurous acid treatment and the remaining organic carbon analyzed by dry combustion. Dry combustion will be carried out using a Perkin Elmer 240C elemental (C, H, N) analyzer with a thermal conductivity detector.

ASTM D 2434: Permeability Coefficient-Constant Head

Permeability coefficient is determined by a constant head method for determining the laminar flowrate of water through granular soils. This procedure is limited to disturbed granular soils containing not more than 10 percent soil passing the 75 micrometer (No. 200) sieve. For this project, measurements were made on minimally disturbed soils samples collected in Shelby Tubes when the bulk density samples were taken.

TMSWC-13: Permeability Coefficient-Falling Head-Solid Cores

This test was carried out on the solidified 7- and 28-day core samples. A cylindrical sample 7.62x7.62 cm was used. Permeability is determined using a triaxial cell measuring changes of water volume over time under controlled conditions of temperature and pressure.

ASTM 1633: Unconfined Compressive Strength Test

This test method covers the determination of the unconfined compressive strength of molded soil-cement cylinders using strain-controlled application of the axial load.

TMSWC-12: Wet/Dry Weathering Test

This test was performed using two 4.5x7.4 cm cylindrical core specimens of solidified wastes. It was carried out in conjunction with TMSWC Method 4.0, Water Content. One of the specimens was used as the test specimen, the other as the control.

Two solidified test samples were compared by weight difference. One sample, the control, was placed in a humidity chamber, and the other was dried in a vacuum oven at 60 $\pm 3^{o}$C for 24 ± 1 hours. The sample specimen then was cooled in a desiccator, and 230 ml of water was added to each sample. The sample and control then were placed in the humidity chamber for 24 hours. This was repeated 11 times, with the weight loss being recorded each time.

TMSWC-11: Freeze/Thaw Test

This test was performed using two 4.5x7.4 cm cylindrical core specimens of solidified waste. The test was carried out in conjunction with the water content determination. One of the two specimens was used as a control. The test specimen was placed in a freezer at -20 $\pm 3^{o}$C for 24 ± 1 hours. Water was then added to the frozen specimen and control and maintained at 22 $\pm 3^{o}$C for 24 ± 1 hours. The process was repeated 11 additional times, with relative weight loss calculated after each cycle.

6.6 CHEMICAL TESTS

The chemical tests described below were used to analyze the soil and leachate samples during this SITE Program.

Toxicity Characteristics Leaching Procedure (TCLP)

The TCLP is designed to determine the mobility of both organic and inorganic contaminants present in liquid, solid, and multiphase wastes. For wastes comprised of solids, the particle size of the waste is reduced and analytes are extracted for 18 hours with an acetic acid solution. The extract is then separated from the solid phase and analyzed for VOC, BNA, Priority Pollutant Metals, PCBs, and oil and grease. This procedure was developed to measure a wider variety of contaminants including volatile organics, than is measured by EP Toxicity.

MCC-1P: Modified Static Leach Test

The static leach test establishes the maximum credible concentrations of elements in a quasi-static groundwater regime that has been in contact with a stabilized waste. The samples are kept as solid cores to simulate an in situ condition. For this project, 28-day cylinders were used from the core barrel drilling. Four test specimens for each test were leached with organic-free ultra pure water, at 40°C for four varying time periods up to 28 days. Leachates then were analyzed for all contaminants.

ANS 16.1: Leach Test

The intact samples, cut from the solid cores, were leached using ultra pure water. The sample specimen is placed in fresh leachates at five different time intervals, with the total leaching time being 28 days. This differs from TCLP and MCC-1P, where each of four specimens is placed in its own leachate and held there for varying time frames up to 28 days. Therefore, five leachates were analyzed for the organic and inorganic contaminants.

EP Toxicity

This extraction procedure is specified by the United States Environmental Protection Agency to classify solid waste as hazardous (or not) according to the characteristic of "EP Toxicity." The solid cores are crushed and agitated for 24 hours with the pH controlled at 5.0. This test specifies only eight metals and six pesticides and herbicides to be measured in the extract.

SW846 Method 3510: Liquid-Liquid Extraction

Method 3510 is a procedure for isolating organic compounds from aqueous samples. A measured volume of sample is serially extracted with methylene chloride using a separatory funnel. The extract is dried, concentrated, and, as necessary, exchanged into a solvent compatible with the cleanup or determinative step to be used.

SW846 Method 3540: Soxhlet Extraction

Method 3540 is a procedure for extracting nonvolatile and semivolatile organic compounds from solids such as soils, sludges, and wastes. The solid sample is mixed with anhydrous sodium sulfate and placed in an extraction thimble. Extract then is dried, concentrated, and, as necessary, exchanged with a solvent compatible with the cleanup or determinative step being employed.

SW846 Method 5030: Purge-and-Trap

Method 5030 describes sample preparation and extraction for the analysis of volatile organics by a purge-and-trap procedure. An inert gas is bubbled through the solution at ambient temperature, and the volatile compounds are transferred from the aqueous to the vapor phase. The vapor is swept through a sorbent column where the volatile components are adsorbed. After purging is completed, the sorbent column is heated and back-flushed with inert gas to desorb the components onto a gas chromatographic column.

EPA Method 8240: Gas Chromatography/Mass Spectrometry (GC/MS for Volatile Organics

Method 8240 is a GC/MS procedure used to determine the concentration of volatile organic compounds in a variety of solid waste matrices. Method 8240 can be used to quantify most volatile organic compounds that have boiling points below 200°C and that are insoluble or slightly soluble in water. These include low-molecular-weight halogenated hydrocarbons, aromatic, nitriles, ketones, acetates, acrylates, ethers, and sulfides. The volatile compounds are introduced into the GC by the purge-and-trap method; detection is by mass spectrometer.

EPA Method 8270: GC/MS for Semivolatile Organics

Method 8270 is a capillary column procedure used to determine the concentration of semivolatile organic compounds in sample extracts. Method 8270 can be used to quantify most neutral, acidic, and basic organic compounds that are soluble in methylene chloride, including polynuclear aromatic hydrocarbons, chlorinated hydrocarbons and pesticides, phthalate esters, organophosphate esters, nitrosamines, haloethers, aldehydes, ethers, ketones, anilines, pyridines, quinolines, aromatic nitro compounds, and phenols.

SW846 Method 8080: GC/ECD for PCBs

Method 8080 provides gas chromatographic conditions for the detection of PCBs. Prior to analysis, samples are subject to appropriate extraction procedures. Samples are injected into the GC using the solvent flush technique. Compounds in the GC effluent are detected by an electron capture detector (ECD).

SW836 Method 680: GC/MS for PCBs

Method 680 covers determination of pesticides and polychlorinated biphenyls (PCBs) in waters, soils, and sediments by gas chromatography/mass spectrometry (GC/MS). It is applicable to samples containing single congeners or to samples containing complex mixtures, such as Aroclors. Polychlorinated biphenyls (PCBs) are identified and measured as isomer groups by levels of chlorination.

SW846 Method 3050: Acid Digestion for Metals

Method 3050 is an acid digestion procedure used to prepare sediments, sludges, and soil samples for analysis by flame or furnace Atomic Absorption (AA) spectroscopy, or for analysis by inductively coupled plasma atomic emissions spectroscopy (ICPES). A representative sample is digested in HNO_3 and H_2O_2. The digestate is then refluxed with either NHO_3 or HCl.

SW846 Method 3010: Acid Digestion for Metals

Method 3010 is a digestion procedure used to prepare samples for analysis by flame AA and ICPES. The sample is mixed with HNO_3 and allowed to reflux in a covered Griffin breaker followed by refluxing with HCl.

SW846 Method 3020: Acid Digestion for Metals

Method 3020 is a digestion procedure used to prepare samples for analysis by graphite furnace AA spectroscopy. The sample is mixed with HNO_3 and allowed to reflux in a covered Griffin breaker. The digestate is then diluted to achieve a reconstituted sample containing 3% by volume HNO_3.

SW846 Method 6010: Metals by ICPES

Method 6010 describes the simultaneous, or sequential, determination of elements using ICPES. The method measures element-emitted light by optical spectrometry. Samples are nebulized, and the resulting aerosol is transported to the plasma torch. Element-specific atomic-line emissions spectra are produced, which are dispersed by a grating spectrometer and monitored for intensity by photomultiplier tubes.

SW846 Methods 7060/7421/7740/7841: Furnace AA

Methods 7060, 7421, 7740, and 7841 are graphite furnace atomic absorption techniques approved for determination of arsenic, lead, selenium, and thallium, respectively. Following sample digestion, an aliquot of sample is placed in a graphite tube in the furnace, evaporated to dryness, charred, and atomized. The metal atoms to be measured are placed in the light path of an atomic spectrophotometer.

SW846 Method 7470/7471: Mercury by Cold Vapor Atomic Absorption (CVAA)

Method 7470 is a cold-vapor atomic absorption procedure for determining the concentration of mercury in mobility-procedure extractions. Method 7471 is prescribed for solid and sludge-type wastes. Sample preparation is specified in each method. Following dissolution, mercury in the sample is reduced to the elemental state and aerated from solution in a closed system. The mercury vapor passes through a cell positioned in the light path of an atomic absorption spectrophotometer.

6.6.1 Contaminant Definitions

Priority Pollutant Metals

Thirteen priority pollutant metals have been specified to be of particular environmental concern by the United States Environmental Protection Agency. The metals are antimony, arsenic, beryllium, cadmium, chromium, copper, lead, mercury, nickel, selenium, silver, thallium, and zinc. Six of these metals were found in measurable concentrations in contaminated soils from the Douglassville site. To conserve resources, only the six metals found at the site were analyzed for in many of the samples tested. The six metals found were cadmium, chromium, copper, lead, nickel, and zinc.

Base Neutral/Acid Exractables (BNA)

Semivolatile organic compounds are prepared for analysis by extraction either into a base-neutral (BN) extract or an acidic (A) extract. Examples of BNAs include phenol, naphthalene, and phthalates.

Volatile Organic Carbon (VOC)

Volatile organic compounds are determined by purging volatiles from the sample tested. Examples include toluene, tetrachloroethene, xylenes, trichloroethene, and ethyl benzene.

Polychlorinated Biphenyls (PCBs)

Polychlorinated biphenyls are a group of related isomers of chlorinated organic compounds characterized by having 1 to 10 chlorine atoms substituted on the biphenyl group.

SECTION 7

ANALYTICAL RESULTS

In each of the following subsections, the results are first presented by plant area and then on an overall basis across the six plant areas. In the overall results presentation, the analytical data are divided into three parts: 1) physical results, such as permeability, moisture content, unconfined compressive strength, etc., 2) chemical analyses of the soils and leachates, and 3) microstructural studies based upon x-ray diffraction and microscopic analyses. The data quality is discussed in Section 7.3.

A discussion and interpretation of the results are presented in Section 8. The full details of the physical and chemical laboratory analyses are provided in Appendix B, and the microstructural study in Appendix C.

7.1 PLANT AREA RESULTS

The results by plant area are presented in the following subsections:

7.1.1 DRUM STORAGE AREA

The results of the physical and chemical analyses for the Drum Storage Area are summarized in Table 7.1. Highlights of these results are as follows:

- The bulk density of the undisturbed soil increased from 1.23 g/ml to almost 2.0 g/ml upon treatment.
- The permeability was reduced by the treatment process from 0.57 to 2.3×10^{-9} cm/sec.
- The unconfined compressive strength was in excess of 1000 psi, with the average of the 7-day cores, 1447 psi, being greater than the average of the 28-day cores, 1113 psi.
- Volatiles were not detected in the untreated soil. After toluene injection, the solidified cores (28-day) indicated only 1.35 ppm by wt. toluene, which is only about 3% of that injected. TCLP leaching test results showed equivalent levels of toluene in the untreated and treated soil leachates. For the untreated soil TCLP test only, toluene was added to the sample to be leached at a dosage level equivalent to that actually measured in the solidified 7-day cores.

TABLE 7.1. DEMONSTRATION TEST RESULTS - DSA

Physical Tests

Parameter	Untreated Soil	Treated soil 7 day	 28 day
Moisture content, %	11.8	14.2	14.8
pH	6.41	-	-
Bulk Density, g/ml (lbs/ft^3)	1.23 (76.8)	1.95 (121.5)	1.99 (124.0)
Oil and Grease, %	1.0	-	0.54
Total organic carbon, %	4.9	-	-
Permeability, cm/sec	0.57	1.6×10^{-9}[a]	2.3×10^{-9}
Unconfined compressive strength, psi	-	1447	1113

Chemical Tests

Parameter	Soils, ppm by wt. Untreated	 7-day[b]	 28-day	TCLP extracts, mg/l Untreated	 7-day	 28-day
Total VOC	ND	1.35	1.32	0.915	0.384	0.376
Toluene[c]	ND	1.35	1.24	0.915	0.380	0.370
Total BNA	12.15	-	ND	ND	0.05	ND
Phthalates	12.15	-	ND	ND	ND	ND
Phenols	ND	-	ND	ND	0.04	ND
Metals - Pb	3230	-	830	1.500	0.015	0.007
Total PCBs	1.2	-	-	ND	ND	ND
Oil and grease, %	1.0	-	0.54	ND	0.63	4.3

(a) This 7-day value is calculated based on a test value at 28+ days of curing.

(b) Only VOC tests were performed on 7-day cores.

(c) Toluene injected into treated slurry.

ND Not detected

- The feed soil contained about 12 ppm by wt. BNA, essentially only phthalates. The treated soil did not show any phthalates nor did any of the leachates.
- The lead content in the soil was 3230 ppm by wt. The results from the leachate analyses showed decreasing extraction concentrations from untreated soil to 28-day cores.
- The PCB level in the soil was 1 ppm by wt. PCBs were not detected in the leachates.
- The oil and grease content of the soil was 1.0%. The concentrations measured in the treated cores, based upon a material balance, are consistent. Leachate results showed increasing quantities, from undetected in untreated soil to 4.3 mg/l in the 28-day cores.

7.1.2 LAGOON NORTH

The results of the physical and chemical analyses for Lagoon North are summarized in Table 7.2. Highlights of these results are as follows:

- The bulk density of the undisturbed soil increased upon treatment from 1.4 to 1.6 g/ml.
- The permeability was reduced by the treatment process from $1.8\text{x}10^{-3}$ to less than $3.6\text{x}10^{-9}$ cm/sec.
- The unconfined compressive strength was approximately 430 psi after 7 days and 520 psi after 28 days of curing.
- Total volatiles in the soil was measured as 2.41 ppm by wt. with equivalent values measured in the treated soil samples. The TCLP leaching tests, for untreated and treated soil samples, gave equivalent leachate concentrations, all under 50 ug/l. The special leach tests, ANS 16.1 and MCC-1P did not detect any volatiles in the leachates.
- The feed soil contained nearly 21 ppm by wt. BNA with the phthalates predominant. After treatment the phthalates were not detected, but high levels of phenols were measured. The concentration of BNAs in the leachates, whether treated or untreated, was about 1 ppm by wt, virtually all phenols. The results from the MCC-1P leach test were equivalent to the TCLP results and showed higher concentrations of BNAs than ANS 16.1 leachate results by a factor of two.
- The lead content in the soil was 9200 ppm by wt. and in the TCLP leachate, just below 32 mg/l. After soil solidification and 7 days of curing, the concentration in the leachates was reduced to near detection limits of approximately 0.005 mg/l. The concentration in the ANS

TABLE 7.2. DEMONSTRATION TEST RESULTS - LAN

Physical Tests

Parameter	Untreated Soil	Treated soil 7-day	Treated soil 28-day	Base case: Soil + cement(b)
Moisture content, %	17.6	20.1	17.2	20.6
pH	3.69	-	-	-
Bulk Density, g/ml (lbs/ft^3)	1.4 (87.3)	1.61 (100.3)	1.59 (99.1)	1.55 (96.6)
Oil and Grease, %	16.5	-	7.54	-
Total organic carbon, %	23.0	-	-	-
Permeability, cm/sec	1.8x10^{-3}	1.7x10^{-9}(a)	3.6x10^{-9}(a)	3.8x10^{-8}
Unconfined compressive strength, psi	-	427	523	539

Chemical Tests

Parameter	Soils, ppm by wt. Untreated	Soils, ppm by wt. 7-day	Soils, ppm by wt. 28-day	TCLP extracts, mg/l Untreated	TCLP extracts, mg/l 7-day	TCLP extracts, mg/l 28-day
Total VOC	2.44	1.95	3.55	0.02	0.008	0.05
Toluene	1.0	0.52	1.28	0.01	ND	0.04
Total BNA	20.9	-	42.8	1.02	1.34	1.45
Phthalates	15.7	-	ND	.01	.03	.01
Phenols	5.2	-	32.4	1.01	1.31	1.44
Metals - Pb	9200	-	2800	31.8	ND	0.005
Total PCBs	51	-	-	ND	ND	ND
Oil and grease, %	16.5	-	7.54	1.3	4.1	2.2

(a) These 7-day values are calculated based on test values at 28+ days of curing.
(b) Solidified soil, without the use of Chloranan, after 28 days of curing.
ND Not detected

16.1 leachates were 0.01-0.05 mg/l and for MCC-1P 0.07 to 0.11 mg/l. In both special leach tests, the concentration in the extracts increased with time.

- The PCB content of the soil was 51 ppm by wt. PCBs were not detected in any leachates.

- The oil and grease level in the untreated soil was 16.5% by wt. and in the 28 day cores, 7.54%. The concentration measurements for the treated cores, based upon a material balance, are consistent. The concentration in the TCLP leachates for untreated soil was approximately 1 mg/l and slightly greater in the treated soil leachates, ranging from 2-4 mg/l.

- The physical properties of the base case samples, prepared in Radian's laboratory without Chloranan, after 28 days of curing were similar to the HAZCON treated material, except that the permeability was greater by a factor of approximately ten.

7.1.3 FILTER CAKE STORAGE AREA

The results of the physical and chemical analyses for the Filter Cake Storage Area are summarized in Table 7.[illegible] Highlights of these results are as follows:

- The bulk density of the undisturbed and untreated soil was 1.6 g/ml and appears to decrease by 5% after treatment. Cores prepared in the laboratory without Chloranan were 15% lower in bulk density than the undisturbed soil sample.

- The permeability of the treated soil, taken as a slurry in the field (7-day), was 4.5×10^{-9} cm/sec and for the 28-day cores, 8.4×10^{-8} cm/sec. The laboratory sample, without Chloranan, was 3.2×10^{-8} cm/sec.

- The unconfined compressive strength after 28 days of curing was 219 psi. The samples without Chloranan, from the base case study, averaged 38 psi.

- The total volatiles in the soil was 150 ppm by wt. with the treated core values lower. The TCLP extracts for treated and untreated soils were 0.71-1.03 mg/l. The leachate concentrations from the MCC-1P leach test were equivalent to those of TCLP and greater than for ANS 16.1 by a factor of two.

- The filter cake contained about 500 ppm by wt BNA with most of it being phenols. Upon leaching, whether the soil was treated or untreated, the leachate contained 2.7-3.8 mg/l phenols, with the phthalates and naphthalene at detection limits. The treated soil showed a sharp decrease in phthalates. In these samples more naphthalene

TABLE 7.3. DEMONSTRATION TEST RESULTS - FSA

Physical Tests

Parameter	Untreated Soil	Treated soil 7-day	Treated soil 28-day	Base case: Soil + cement(b)
Moisture content, %	24.7	24.7	22.1	28.9
pH	2.56	-	-	-
Bulk Density, g/ml (lbs/ft^3)	1.60 (99.7)	1.51 (94.1)	1.51 (94.1)	1.36 (84.7)
Oil and Grease, %	25.3	-	9.54	-
Total organic carbon, %	27.5	-	-	-
Permeability, cm/sec	(a)	4.5×10^{-9}	8.4×10^{-8}	3.2×10^{-8}
Unconfined compressive strength, psi	-	238	219	38

Chemical Tests

Parameter	Soils, ppm by wt. Untreated	Soils, ppm by wt. 7-day	Soils, ppm by wt. 28-day	TCLP extracts, mg/l Untreated	TCLP extracts, mg/l 7-day	TCLP extracts, mg/l 28-day
Total VOC	150	113.3	105.3	1.03	0.71	0.74
Toluene	26	20.7	19	0.25	0.22	0.23
Total BNA	534	-	368.9	2.86	3.91	2.78
Phthalates	14.2	-	1.3	ND	ND	0.01
Phenols	405	-	126.8	2.81	3.85	2.72
Naphthalene	115	-	216.7	0.05	0.06	0.06
Metals - Pb	22600	-	10300	17.9	0.07	0.41
Total PCBs	40	-	-	ND	ND	ND
Oil and grease, %	25.3	-	9.45	3.7	4.1	10.4

(a) Could not be measured

(b) Solidified FSA soil, without the use of Chloranan, after 28 days of curing

ND Not detected

was observed than all the phenols. The leachate concentrations from MCC-1P were equivalent to the TCLP leachates and greater than those from ANS 16.1.

- The lead content in the soil was about 2.3% by wt. The 28-day treated soil TCLP leachates averaged 0.4 mg/l, with the 7-day values less than 0.1 mg/l. The MCC-1P leach test extracts contained equivalent amounts of lead and the concentrations in ANS 16.1 extracts were less, in the range of 0.05-0.47 mg/l.
- The PCBs in the untreated soil were 40 ppm by wt, but they were not detected in the leachates.
- The oil and grease content in the untreated soil was 25.3% and 9.45% by wt in the treated soil, which is consistent on a material balance basis. The leachate results ranged from 4.1-10.4 mg/l, with the treated soil samples slightly higher in oil and grease. The special leach tests' leachate concentrations were the same as in the TCLP extracts.

7.1.4 LANDFARM AREA

The results of the physical and chemical analyses for the Landfarm Area are summarized in Table 7.4. Highlights of these results are as follows:

- The bulk density of the untreated and undisturbed soil was 1.68 g/ml and increased after solidification to 1.86 g/ml.
- The permeability of the soil upon treatment in the HAZCON process decreased from $2x10^{-2}$ to $4.5x10^{-9}$ cm/sec.
- The unconfined compressive strength of the cores was approximately 945 psi after both 7 and 28 days of curing.
- The total volatiles in the soil was below detection limits. Analysis of the 28-day cores showed that about 40% of the toluene spike remained with the treated soil. TCLP leachate results showed a VOC concentration (toluene only) of 0.37 mg/l.
- The LFA soil contained about 37 ppm BNA, with this being predominantly phthalates with some naphthalene. The TCLP leachates, for both the treated and untreated soils, were near the detection limits of each component of 10 ug/l.
- The lead content in the untreated soil was 1.37% by wt. The TCLP leachate, after the soil was treated, had a concentration of 0.05 mg/l as compared to the untreated soil leachate of 27.7 mg/l.
- The PCBs in the soil were 10 ppm by wt. PCBs were not detected in any of the leachates.

TABLE 7.4. DEMONSTRATION TEST RESULTS - LFA

Physical Tests

Parameter	Untreated Soil	Treated soil	
		7-day	28-day
Moisture content, %	16.7	17.0	15.1
pH	4.57	-	-
Bulk Density, g/ml (lbs/ft^3)	1.68 (104.6)	1.84 (114.6)	1.86 (115.9)
Oil and Grease, %	4.3	-	-
Total organic carbon, %	8.9	-	-
Permeability, cm/sec	2×10^{-2}	4.5×10^{-9}	4.5×10^{-9}
Unconfined compressive strength, psi	-	947	945

Chemical Tests

	Soils, ppm by wt.			TCLP extracts, mg/l		
Parameter	Untreated	7 day	28-day	Untreated	7-day	28-day
Total VOC	ND	12.1	24.7	0.21	0.21	0.37
Toluene(a)	ND	12.1	23.7	0.21	0.21	0.37
Total BNA	36.7	-	ND	0.01	0.05	0.10
Phthalates	33.5	-	ND	0.01	0.01	0.02
Phenols	ND	-	ND	ND	0.03	0.08
Metals - Pb	13700	-	1860	27.7	0.04	0.05
Total PCBs	10	-	-	ND	ND	ND
Oil and grease, %	4.3	-	1.53	2.0	2.8	1.9

(a) Toluene injected into treated slurry at a target concentration equivalent to 125 ppm by wt. in the untreated soil.

(b) Values vary from 0.13 to 28 ppm; averaged lower two values.

ND Not detected

- The oil and grease level in the untreated soil was 4.3% by wt. The treated soil content, after correcting for the addition of cement, water, and Chloranan, was consistent with the untreated soil. The TCLP leachates for treated and untreated soil samples were both about 2 mg/l.

7.1.5 PLANT FACILITY AREA

The results of the physical and chemical analyses for the Plant Facility Area are summarized in Table 7.5. Highlights of these results are as follows:

- The bulk density of undisturbed soil increases from 1.73 mg/l to 2.02 mg/l after solidification.
- The permeability of the untreated soil was 7.7×10^{-2}. The treated soil had values ranging from 1.2×10^{-8} to 2.5×10^{-10} cm/sec.
- The unconfined compressive strength reached 1574 psi after 28 days.
- The total volatiles in the untreated soil was 0.42 ppm. However, the 28 day cores showed approximately 23 ppm volatiles with approximately 18 ppm being injected toluene. The VOC concentrations in the TCLP extracts, for both the untreated and treated soil samples, were in the approximate range of 0.7-1.0 mg/l. The VOC concentrations in the leachate from both special leach tests were less than the TCLP values by a factor of 5-10.
- The PFA soil contained approximately 18 ppm by wt BNA, phthalates and naphthalene. The values for the leachate concentrations in untreated and treated soils were less than 0.11 mg/l. The leachates for MCC-1P and ANS 16.1 were comparable to the TCLP extracts.
- The lead content in the soil was approximately 0.8%. The TCLP leachates, after treatment, showed a concentration of 0.01 mg/l. This is equivalent to the leachates from ANS 16.1, but significantly less than those of MCC-1P where the leachate concentrations were higher, as high as 0.7 mg/l for the 14-day leaching interval.
- The PCBs in the soil totaled 34 ppm by wt. PCBs were not detected in any of the leachates.
- The oil and grease content of the soil was 4.5% by wt. The concentration in the treated cores averaged 2.1% by wt., which is consistent for a material balance. The TCLP leachate results ranged from 0.4 to 3.5 mg/l, with the leachate concentrations of the treated soil slightly greater. The oil and grease concentrations for ANS 16.1 and MCC-1P ranged from undetected to 1.7 mg/l.

TABLE 7.5. DEMONSTRATION TEST RESULTS - PFA

Physical Tests

Parameter	Untreated Soil	Treated soil 7-day	 28-day
Moisture content, %	6.6	11.6	10.0
pH	7.00	-	-
Bulk Density, g/ml (lbs/ft^3)	1.73 (108.0)	2.07 (129.0)	2.02 (125.8)
Oil and Grease, %	4.5	-	-
Total organic carbon, %	7.5	-	-
Permeability, cm/sec	7.7×10^{-2}	1.2×10^{-8}(a)	1.2×10^{-8}(b)
Unconfined compressive strength, psi	-	1435	1574

Chemical Tests

Parameter	Soils, ppm by wt. Untreated	 7-day	 28-day	TCLP extracts, mg/l Untreated	 7-day	 28-day
Total VOC	0.42	4.6	22.7	1.1	0.37	0.83
Toluene(b)	ND	4.6	17.7	1.1	0.35	0.67
Total BNA	18.4	-	4.13	0.01	0.09	0.11
Phthalates	10.7	-	ND	0.01	0.02	0.03
Phenols	ND	-	ND	ND	0.05	0.08
Naphthalene	7.7	-	4.13	ND	0.02	ND
Metals - Pb	7900	-	3280	22.4	0.009	0.01
Total PCBs	34	-	-	ND	ND	ND
Oil and grease, %	4.5	-	2.11	0.4	1.0	3.5

(a) Largest value shown - other two values average 4.7×10^{-10} cm/sec

(b) Largest value shown - other two values average 1.5×10^{-9} cm/sec

ND Not detected

7.1.6 LAGOON SOUTH

The results of the physical and chemical analyses for Lagoon South are summarized in Table 7.6. Highlights of these results are as follows:

- The bulk density of the undisturbed soil sample increases from 1.59 g/ml to 1.74 g/ml after being treated in the HAZCON process.
- The permeability of the soil was reduced from 1.5×10^{-5} to 2.2×10^{-9} cm/sec after soil treatment.
- The unconfined compressive strength was approximately 890 psi for both the 7- and 28-day core samples.
- The total volatiles in the untreated soil was 6.5 ppm by wt. The concentrations appear to be the same after soil treatment. The VOC concentrations of the TCLP extracts were equivalent, in the range of 0.03-0.11 mg/l. For the special leach tests, extract concentrations were lower, being close to the detection limits of 0.01 mg/l.
- The LAS untreated soil samples showed only phthalates as the BNA at a concentration of 34.2 ppm by wt. However, in the 28-day cores, phenols, and naphthalene exist and are the predominant compounds. The TCLP leachate concentrations were greater for the treated soil, with the primary compounds being phenols. The MCC-1P leachate concentrations were equivalent to the TCLP extracts and greater than for ANS 16.1.
- The lead content in the soil was 1.49% by wt. The untreated soil TCLP leachate was 52 mg/l, but after treatment this was reduced to 0.05 mg/l, which is approximately equal to the maximum leachate concentrations for ANS 16.1. The leachates for MCC-1P were in the range of 0.3-0.5 mg/l for all the time intervals.
- The PCB concentration in the soil was 52 ppm by wt. PCBs were not detected in any leachates.
- The untreated soil contained 7.82% oil and grease. The treated soil values were very erratic, ranging from 0.06% to 4.25% by wt. A material balance could not be confirmed. The leachates concentrations for untreated and treated soils were 0.6 mg/l and approximately 2.1 mg/l, respectively.

7.2 OVERALL RESULTS

7.2.1 PHYSICAL TEST RESULTS

TABLE 7.6. DEMONSTRATION TEST RESULTS - LAS

Physical Tests

Parameter	Untreated Soil	Treated soil 7-day	Treated soil 28-day
Moisture content, %	11.9	16.3	15.8
pH	4.11	-	-
Bulk Density, g/ml (lbs/ft^3)	1.59 (99.1)	1.70 (105.9)	1.74 (108.4)
Oil and Grease, %	7.82	-	-
Total organic carbon, %	14.3	-	-
Permeability, cm/sec	1.5×10^{-5}	2.4×10^{-9}	2.2×10^{-9}
Unconfined compressive strength, psi	-	894	889

Chemical Tests

Parameter	Soils, ppm by wt. Untreated	Soils, ppm by wt. 7-day	Soils, ppm by wt. 28-day	TCLP extracts, mg/l Untreated	TCLP extracts, mg/l 7-day	TCLP extracts, mg/l 28-day
Total VOC	6.5	6.29	7.20	0.05	0.02	0.11
Toluene	0.3	0.79	1.78	0.01	0.02	0.05
Total BNA	39.6	-	15.7	0.01	0.47	0.73
Phthalates	34.2	-	2.15	ND	ND	0.08
Phenols	ND	-	6.70	ND	0.47	0.65
Naphthalene	5.4	-	4.55	0.01	ND	ND
Metals - Pb	14900	-	3200	52.6	0.13	0.05
Total PCBs	52	-	-	ND	ND	ND
Oil and grease, %	7.82	-	1.67(a)	0.6	2.55	1.6

(a) Results very erratic from 0.06 to 4.25%.

The results of the physical tests, the full details of which are in Appendix B, are summarized in Tables 7.7 and 7.8. An overview of the individual plant area results are presented below:

7.2.1.1 UNTREATED SOIL

- The soil pH ranged from 2.5 for FSA to 7.0 for PFA.
- The particle size distribution shows that PFA had the coarsest and DSA the finest soil. For most samples except PFA, 30-60% by wt. of the soil was finer than 200 mesh (74 microns).
- The average of three samples for the undisturbed soil bulk density ranged from 1.23 g/ml for DSA to 1.73 mg/ml for PFA.
- The oil and grease (O&G) in the soil ranged from 1.02% to 25.3% by wt. The Total Organic Carbon (TOC) ranged from 4.9% to 27.3% by wt. The highest values for both were for FSA, the lowest for DSA.
- The permeability analyses for the feedstock ranged from 0.57 cm/sec for DSA to 1.5×10^{-5} cm/sec for LAS. The FSA samples were too impermeable to measure.

7.2.1.2 TREATED SOIL - 7 AND 28 DAYS

The averaged results of the 7-day and 28-day samples are presented in Table 7.8. The results can be summarized as follows:

- The bulk density ranged from 1.51 g/ml (94.2 lb/cu ft) for FSA to 2.02 g/ml (125.8 lb/cu ft) for PFA. The values are approximately the same at 7 and 28 days and are 10-20% greater than for the undisturbed, untreated soil. The largest increase in bulk density is for PFA, and FSA had a bulk density decrease of about 5%.
- The moisture content ranged from 11.6% for PFA to 24.7% for FSA at 7 days. At 28 days the range was 10.0% for PFA to 22.1% for FSA.
- The unconfined compressive strength ranged from 238 psi for FSA to 1446 psi for DSA at 7 days. At 28 days it ranged from 219 psi for FSA to 1574 psi for PFA. These values are the same order of magnitude at both 7 and 28 days.
- The permeability ranged for the 7-day cores from 1.6×10^{-9} cm/sec for DSA to 4.5×10^{-9} cm/sec for FSA and LFA. At 28 days it ranged from 8.4×10^{-8} cm/sec to 1.8×10^{-9} cm/sec for FSA and DSA, respectively. This compares to 10^{-1} to 10^{-5} cm/sec for untreated soils.

TABLE 7.7. PHYSICAL PROPERTIES OF UNTREATED SOILS

	UNTREATED SOIL						
Plant Area	Moisture Content Weight %	pH	Bulk Density[(a)] g/ml	Oil & Grease[(c)] Weight %	Total Organic Carbon Weight %	Permeability, cm/sec[(b)]	Less than 200 mesh (74u), %
DSA	11.8	6.41	1.23	1.0	4.9	5.7×10^{-1}	58
LAN	17.6	3.69	1.40	16.5	23.0	1.8×10^{-3}	37
FSA	24.7	2.56	1.60	25.3	27.5	Impermeable(d)	NA(d)
LFA	16.7	4.58	1.68	4.3	8.9	2.0×10^{-2}	57
PFA	6.6	7.00	1.73	4.5	7.5	7.7×10^{-2}	19
LAS	11.9	4.11	1.59	7.8	14.3	1.5×10^{-5}	47
Clean Soil	15.7	6.43	1.63(e)	0.26	0.1	6.0×10^{-3}	32
Table	A-2	A-2	A-1	A-7	A-7	A-1	

(a) Values reported are of undisturbed soil samples except for clean soil.

(b) Permeability as measured by constant head permeability test.

(c) Oil and Grease is fraction of TOC extracted by a solvent.

(d) Could not be run due to excessive stickiness.

(e) Compacted loose sand.

TABLE 7.8. PHYSICAL PROPERTIES OF TREATED SOILS

Plant area	7 DAY Moisture %	Bulk density g/ml	Unconfined compressive strength, psi	Permeability[(a)] cm/sec	28 DAY Moisture %	Bulk density g/ml	Unconfined compressive strength, psi	Permeability cm/sec
DSA	14.2	1.95	1447	1.6×10^{-9}	14.8	1.99	1113	1.8×10^{-9}
LAN	20.1	1.61	427	1.7×10^{-9}	17.2	1.59	523	4.0×10^{-9}
FSA	24.7	1.51	238	4.5×10^{-9}	22.1	1.51	219	8.4×10^{-8}
LFA	17.0	1.84	947	4.5×10^{-9}	15.1	1.86	945	4.5×10^{-9}
PFA	11.6	2.07	1435	4.7×10^{-10}(e)	10.0	2.02	1574	5.0×10^{-9}
LAS	16.3	1.70	894	2.4×10^{-9}	15.8	1.74	889	2.2×10^{-9}
Cement Only	9.9	1.98	1758	(d)	11.0	2.07	2947	
Clean(c) Soil & Cement	13.3	1.88	2000	(d)	13.0	2.04	2910	5.9×10^{-9}
FSA &(c) Cement	28.2	1.41	27	(d)	28.9	1.36	38	3.2×10^{-8}
LAN &(c) Cement	19.6	1.60	373	(d)	20.6	1.55	539	3.8×10^{-8}
TABLE	A-14	A-14	A-15	A-14	A-23	A-23	A-24	A-23

(a) Permeabilities all performed after 28 days elapsed.

(b) Table refers to tables in Radian report, Appendix B.

(c) Laboratory formulations prepared without the use of Chloranan.

(d) Not scheduled to be performed.

(e) The two low values averaged 4.7×10^{-10} cm/sec. The third value was 1.2×10^{-8} cm/sec.

- The wet/dry and freeze/thaw weathering tests showed small weight losses (0.5-1.5%) at the end of the 12-cycle test for the test specimens and their controls. Unconfined compressive strength tests performed after the final weathering cycle showed no loss in UCS compared to the unweathered samples.

- Both field- and laboratory-cured samples were used to evaluate the effectiveness of the HAZCON process during the Demonstration test. The laboratory formulations were prepared using cement with clean soil, FSA and LAN soils without Chloranan. For bulk density and moisture, the values were close to field-processed soils. For unconfined compressive strength (UCS) FSA was reduced to 27 psi at 7 days and 38 psi at 28 days. For LAN the UCS values were 373 psi at 7 days and 539 psi at 28 days. These latter values are comparable to the field-treated samples. In comparison, the clean soil produced the highest unconfined compressive strength of 2000 psi. The permeabilities of the laboratory-formulated samples were in the range of 3.8×10^{-8} for LAN to 5.9×10^{-9} for clean soil and cement. The values are equivalent to the field results for FSA but a factor of about ten greater for LAN.

It should be noted that due to the difficulties and time required to perform the permeability tests, these tests were run anywhere from 6 to 15 weeks after the soils were treated.

7.2.2 CHEMICAL ANALYSES

7.2.2.1 UNTREATED SOIL ANALYSES

The results of the untreated soil analyses are reported in Appendix B and summarized in Table 7.9. They can be highlighted as follows:

- Oil and grease ranged from 1.0% by wt. for DSA to 25.3% by wt. for FSA. The oil and grease levels in the 28-day treated cores were about 40% of the untreated soils as would be anticipated from the material balances.

- Total PCBs ranged from 1.2 ppm for DSA to 52 ppm by wt. for LAS. Most of the PCBs were Aroclor 1260. However, Aroclor 1248 was measured at 19 ppm by wt. in PFA and 25 ppm by wt. in LAS. In the other areas, Aroclor 1248 was below detection limits of 20 parts per billion by wt. Aroclor 1260 was measured in all six plant areas. These values are greater than those reported in the screening study, whose samples were collected in May 1987 and are reported in Table 4.1.

- The thirteen priority pollutant metals were analyzed for in the untreated soil. Lead is the predominant metal contaminant. Five other metals of measurable concentration were analyzed for in the 28-day cores and leachates. These other metals are chromium, nickel,

TABLE 7.9. CHEMICAL ANALYSES OF UNTREATED SOILS

Chemical Analyses	DSA	LAN	FSA	LFA	PFA	LAS
PCBs						
Aroclor 1260	1.2	51	40	10	14.5	25
Aroclor 1248	ND	ND	ND	ND	19	27
Oil and Grease, % by wt.	0.98	16.5	25.3	4.27	4.47	7.80
Metals - ppm by wt						
Lead	3,230	9,250	22,600	13,670	7,930	14,830
Chromium	24	19	31	46	95	73
Nickel	23	6	8	22	46	17
Cadmium	1	2.3	6	4	5.5	3.5
Copper	74	35	128	90	440	140
Zinc	315	150	655	735	1,600	580
BNA - ppb by wt						
All phthalates	12,150	15,700	14,200	33,500	10,750	34,200
All phenols	ND	5,200	405,000	ND	ND	ND
Naphthalene	ND	ND	115,000	3,200	7,700	5,400
Volatiles - ppb by wt						
Toluene	ND	1,000	26,000	ND	ND	290
Trichloroethene	ND	130	13,800	ND	ND	580
Tetrachloroethane	ND	160	6,100	ND	100	1,500
Ethyl Benzene	ND	180	13,000	ND	ND	400
Xylenes	ND	970	91,000	ND	320	3,700

ND - None detected.

cadmium, copper, and zinc. The average of the analyses in the six areas shows that lead exists in concentrations from 0.3% to 2.3% by wt. Chromium, nickel, and cadmium exist at concentration levels of less than 100 ppm by wt. with cadmium the least. Copper and zinc are at concentrations of a few hundred ppm by wt. These overall levels agree with the values obtained from the screening samples.

- Analyses for BNA showed that all areas contained phthalates, primarily di-n-butylphthalate and bis(2-ethylhexyl)phthalate. Total phthalate concentrations up to 34 ppm by wt. in LAS were measured. Phenols were also abundant, with total concentrations over 400 ppm measured in the FSA. Naphthalene also was detected in the soil in all areas except DSA and LAN with concentrations over 100 ppm by wt. at FSA. Bis(2-ethylhexyl)phthalate was the primary semivolatile detected in the screening samples.

- Volatiles were not detected in the soil samples at DSA and LFA. The primary volatiles detected were toluene, xylene, trichloroethene, tetrachloroethene, and ethyl benzene. Some samples also contained 1,1,1-trichloroethane and trans-1,2-dichloroethene. The maximum volatiles, based upon multiple sample averaging, were measured at FSA with up to 14 ppm by wt. trichloroethene, 6 ppm tetrachloroethene, 26 ppm toluene, and 91 ppm xylenes. The area with the second largest quantity of volatiles is LAS with maximum sample values primarily in the range for each component of 0.3-3.7 ppm by wt. Toluene was injected into the slurry samples exiting the HAZCON unit for DSA, LFA, and PFA, to produce an equivalent concentration in the feed soil of approximately 125 ppm by wt. Concentrations of the injected toluene in the 7-day core samples ranged from 1.3 ppm by wt. in DSA to 12 ppm in LFA. The toluene in the 28-day core samples ranged from a minimum at DSA of 1.3 ppm by wt. to a maximum at LFA of 24 ppm by wt.

7.2.2.2 LEACHATE ANALYSES

Results of the leachate analyses, for which data reduction calculations are provided in Appendix D, are highlighted as follows:

- The TCLP leachates of the six feedstock soils showed very low oil and grease. For each area, the treated soil leachate concentrations were greater than for untreated soil leachates, even though the untreated soil concentrations are greater on average by a factor of 2.5. The values were from below the detection limits (0.2 mg/l) for DSA to 3.7 mg/l at FSA. The leachate results for the 7- and 28-day cores appear higher than the untreated soil, ranging from 0.6 ppm by wt. for DSA to 4.1 ppm for LAN and

FSA at 7 days, and 1.6 to 10.4 ppm by wt. for LAS and FSA, respectively at 28 days.

- PCBs were not detected in any leachate, whether the soil was treated or untreated.

- The 7- and 28-day TCLP leachates for metals showed that the quantity of metals in the treated soil leachates (see Table 7.10) is well below that for untreated soils. For the 7- day and 28- day cores leachates, except for lead, all the metal concentration levels were near or below detection limits. The lead concentrations were close to detection limits, at levels of about 2-90 ug/liter except for FSA, where the concentration ranged from 7-950 ug/l, averaging 400 ug/l. For the untreated soils, chromium and copper were below detection limits and cadmium and nickel were near the detection limits. The lead concentration ranged from 1.5 mg/l for DSA to 52.6 mg/l for LAS. For zinc, the values ranged from 0.7 mg/l for DSA to 23.0 mg/l for FSA. The solidification process reduced the lead concentration by a factor of about 500 to 1000. TCLP data on the 28-day cores were equivalent to the 7-day cores.

  The leachate concentrations from ANS 16.1 were generally equivalent to those of TCLP, while those of MCC-1P were greater by a factor of 5-10. The leachate concentrations increased with increased leaching time for both tests.

- For the BNAs, very significant reductions in concentrations were obtained between the soil and the TCLP leachates of the untreated, 7-, and 28-day cores. The phthalates, as a group, for all leachates were reduced to approximately their detection limit of 0.010 mg/l. This may be because the phthalates concentrations were very significantly reduced from the untreated soils to the treated soils. For the phenols, measurable quantities in the leachates were observed. For FSA, where the soil samples contained about 400 ppm by wt, leachate concentrations of 3-4 mg/l were measured. In each area, concentrations in the untreated soil, 7-day, and 28-day core leachates were approximately the same, even though the concentrations in the cores were less than one-half that in the untreated soil. The same trend existed for naphthalene, except at lower concentrations. Table 7.11 provides a summary of the leachate concentrations.

  The special leach tests, performed only on 28 day cores, provided results that showed that the leachate concentrations from MCC-1P were equivalent to TCLP leachates, but greater than for ANS 16.1. For the ANS 16.1 leachates, concentration did not appear to be a function of leaching time. However, for MCC-1P the phenol concentrations in the extracts increased with time, but the phthalates and naphthalene did not.

TABLE 7.10. CONCENTRATION OF METALS IN TCLP LEACHATES

	Metal Concentration - mg/liter*					
Soil Location	Pb	Cr	Ni	Cd	Cu	Zn
Soil						
DSA	1.5	<0.008	0.02	<0.004	<0.03	0.07
LAN	31.8	<0.008	0.07	0.02	<0.03	1.1
FSA	17.9	0.27	0.11	0.13	<0.3	23.0
LFA	27.7	<0.008	0.06	0.03	<0.08	6.7
PFA	22.4	<0.008	0.05	0.01	<0.03	1.4
LAS	52.6	<0.008	0.07	0.04	0.13	4.8
7-Day Cores						
DSA	0.015	<0.07	<0.15	<0.04	<0.06	<0.02
LAN	<0.002	<0.07	<0.15	<0.04	<0.06	<0.02
FSA	0.07	0.02	<0.008	<0.003	<0.03	0.02
LFA	0.04	<0.07	0.15	<0.04	<0.06	0.04
PFA	0.01	<0.07	0.15	<0.04	<0.06	<0.02
LAS	0.14	<0.008	<0.008	<0.003	<0.05	0.04
28-Day Cores						
DSA	0.007	<0.007	0.020	<0.004	0.023	0.037
LAN	0.005	0.007	<0.015	<0.004	0.010	0.017
FSA	0.400	<0.070	<0.15	<0.040	<0.060	0.037
LFA	0.050	0.009	0.015	<0.004	0.080	0.013
PFA	0.011	<0.007	<0.015	<0.004	0.027	0.030
LAS	0.051	0.015	0.025	<0.004	0.055	0.258

* Where the symbol < is used, indicates values below detection limits of quantity shown. The detection limits vary between metals and from analysis to analysis.

Where 2 of 3 values were above detection limits, three values were averaged assuming the one below detection limits is zero. If only one of three values are above detection limits, the results are reported as below detection limits.

TABLE 7.11. BASE NEUTRAL/ACID EXTRACTABLES IN TCLP LEACHATES

BNA	Concentration - ug/l DSA	LAN	FSA	LFA	PFA	LAS
Untreated Soil						
phthalates	ND	10	ND	10	10	ND
phenols	ND	1010	2810	ND	ND	ND
naphthalene	ND	ND	50	ND	ND	10
7-Day Cores						
phthalates	ND	30	ND	10	20	ND
phenols	40	1310	3850	30	50	470
naphthalene	15	ND	60	10	20	ND
28-Day Cores						
phthalates	ND	10	10	20	30	80
phenols	ND	1440	2720	80	80	650
naphthalene	ND	ND	60	ND	ND	ND

ND - Not Detected

- For the volatile organics, the primary compounds detected were trichloroethene, tetrachloroethene, xylenes, ethyl benzene, and toluene. During the Demonstration Test operations, toluene was injected into the slurry mix zone of the HAZCON MFU for DSA, LFA and PFA as described earlier. For the TCLP leach tests on the untreated soils, toluene was added to the soil at approximately the same concentrations as measured in the 7-day cores. In the TCLP leachates for untreated soils for DSA, LFA, and PFA, toluene concentrations were quite high, 900-5100 ug/l. For FSA, where the feedstock averaged 26 ppm by wt. toluene, the soil leachate averaged 230 ug/l toluene. The other primary volatile organics, trichloroethene, tetrachloroethene, ethyl benzene, and xylenes were greatly reduced in the untreated soil leachates.

  The results of the 7-day and 28-day core leachates are similar in magnitude to the untreated soil, even though the core concentrations are less than one half of the untreated soil. See Table 7.12 for a comparison of the average key volatile organic components in the TCLP leachates.

  The results of the two special leach tests showed that the leachate concentrations were approximately equal. They were lower by about a factor of 2 compared to TCLP extracts. VOC concentrations did not appear to increase with increased leaching time intervals.

- Extraction Procedure Toxicity (EP Tox) tests were performed on 28-day cores for metals only, for LAN and FSA. For LAN, the leachate metals were predominantly lead (Pb) and averaged 0.02 mg/l for cores averaging approximately 0.3% Pb by wt. For FSA, where the cores contained 1.0% by wt. lead, the leachate concentrations averaged 0.21 mg/l. These values appear to be larger for LAN and less for FSA than the TCLP results.

7.2.2.3 WATER CHEMISTRY

An analysis of the process water, supplied by truck from the local fire department, was performed. The water was low in dissolved solids, 340 mg/l, and very low in suspended solids, 1 mg/l, with a pH of 8.05. The primary cations detected were calcium, magnesium, sodium, and silicon. Two of the primary anions detected were sulfate and chloride at concentration levels of 35 mg/l. Details of the water chemistry analyses are provided in Appendix B, Tables A-50 and A-51.

7.2.3 MICROSTRUCTURAL STUDIES

Analyses of the untreated soil and 28-day core samples were performed on a microstructural scale. All analyses were performed more than three months after soil processing. All

TABLE 7.12. VOLATILES IN TCLP LEACHATES[(a)]

	Concentrations - ug/l					
Volatile Organic	DSA	LAN	FSA	LFA	PFA	LAS
Untreated Soil						
Toluene	915	10	245	5100	1100(b)	10
Xylenes	< 50	7	525	< 230	< 180	35
Trichloroethene	< 20	2.4	165	< 95	< 76	8
Tetrachloroethene	< 40	< 4	19	< 210	< 160	5
Ethyl benzene	< 70	< 7	80	< 360	< 290	< 7
7 Day Cores						
Toluene	380	< 6	220	210	350	< 15
Xylenes	3.5	6	340	5	20	15
Trichloroethene	< 10	< 2	105	< 2	< 5	< 5
Tetrachloroethene	< 20	< 4	11	< 4	< 10	< 10
Ethyl benzene	< 40	< 7	60	< 7	< 20	< 20
28 Day Cores						
Toluene	370	40	230	370	670	50
Xylenes	6	8	330	< 6	170	40
Trichloroethene	< 9	2	100	< 9	< 9	8
Tetrachloroethene	< 6	3	20	< 6	< 6	10
Ethyl benzene	< 3	2	60	2	< 3	4

(a) < indicates less than detection limits. Within one sampling area, the detection limit may change between samples. For these, the highest detection limit is shown.

(b) Two values <60 and 2200 ug/l.

samples were studied by scanning electron microscopy (SEM), x-ray diffraction (XRD), and optical microscopy (OM). Energy dispersive x-ray spectrometry (EDXRA) was also performed on selected samples. The type of information to be obtained from each test is:

- X-ray diffractometry - crystalline structure of the soil and hydration products
- Energy dispersive x-ray spectrometry - elemental analysis, i.e., calcium, aluminum
- Microscopy - characterizes crystal appearance, porosity, fractures, and the presence of unaltered soil/waste material

The detailed report with photographs and x-ray diffraction patterns is included in Appendix C.

The results can be summarized as follows:

- The untreated soils consist of quartz and clay minerals, illite, and in some cases kaolinite. The filter storage area feed was low in quartz, as would be expected.
- The solidified samples show crystals of portlandite, ettringite, calcium silicates, calcium aluminate, and sometimes gypsum.
- Abundant pores of various sizes and shapes could be seen in all core samples. Some of the pores include trapped air bubbles. Large cracks also are seen in some of the pores.
- Unhydrated tricalcium silicate was seen in all core samples. In some cases dicalcium silicate was observed, particularly for FSA.
- Several peaks in each x-ray diffraction pattern could not be identified, as known minerals, but were seen both in the soil and core samples. These peaks are likely to be the organics.
- Mixing does not appear to be completely efficient.
- The cores contain unaltered brownish aggregates that were also observed in the untreated soil.

The interpretation of the above observations is presented in section 8.1.3.

7.3 DATA QUALITY ASSURANCE

In Section 7 of the approved Quality Assurance Project Plan (QAPP), it was indicated that various Quality Control (QC) samples would be taken to control and/or assess data quality. These are:

- QC check samples - standard samples of known analyte concentration.
- Laboratory Blanks - deionized water taken through sample preparation steps.
- Field blanks - clean soil samples brought to the field and then analyzed in the laboratory to check for field contaminations.
- Spiked samples - samples were spiked with either known contaminants or surrogate standards to confirm analytical recoveries and thus accuracy of the analyses. Duplicates on the spiked samples were also performed.
- Duplicate samples - duplicate samples from the field were collected and analyzed to confirm soil sample data.

To verify that correct sampling procedures were used, EPA sent a Quality Assurance (QA) team to the field to observe Radian Corporation's sampling procedures. In addition, QA teams went to Radian's laboratories both in Austin, TX and Sacramento, CA to observe and correct, if necessary, procedures being used in the laboratory. The audits found Radian's work satisfactory.

The detailed QA/QC results reported on Radian procedures is provided in Appendix B. Overall the QA/QC data indicated that the measurement data are acceptable and defensible.

The purpose of the QA/QC program was to fulfill two related purposes:

- An organized frame work for sampling and analytical efforts.
- To control data quality within preestablished limits to ensure that it was adequate to achieve the objectives of the program.

The following is a brief summary of the QA analyses:

- Soil samples
    - Blanks--For metals, the blanks showed levels the same as in uncontaminated soil. PCBs were not detected in the reagent blank. Methylene chloride, toluene, acetone, and three other VOCs were detected in the

reagent blanks. Methylene chloride is probably a laboratory contaminant. Only toluene of these six was considered in the VOC analyses, and some errors in these values may exist. Toluene was only one of five VOCs looked at for reporting VOC data.

  - Spiked sample results--All the metals recoveries and almost all the VOC and PCB recoveries were within the acceptance range.

  - Duplicate sample results--Matrix spike duplicates for metals showed excellent repeatability, with a coefficient of variation (CV) less than 5%. Repeatability for VOCs was also acceptable, with a CV of 50%. The repeatability for PCBs, which had a CV within 10%, was acceptable; 50% is the maximum acceptable CV. The repeatabilitity for O&G was good, with almost all CV less than 5%, but wide variations in sample homogeneity was observed.

- Soil sample leachates

  - Blanks--Only acetone was detected in two samples near the detection limits of 5 ug/l and was probably due to laboratory contamination. Metals and PCBs were not detected in the blanks.

  - Spiked samples--Matrix spike recoveries of lead were high; therefore, results for Pb may be biased slightly high. The recovery of the other metals was within the acceptable target range of 80-120% of the theoretical value. Volatile organic matrix and surrogate spikes were all within the acceptance criteria. For PCBs the surrogate spike recovery of the samples was below acceptance limits; therefore the detection limits of these compounds (measured by Method 680) could be slightly greater than the laboratory reported. PCBs were not found in any leachates.

  - Duplicate samples--Results for VOC and O&G all met acceptance criteria. Duplicates for untreated metals samples were not performed, but duplicates for metals in treated samples showed very low CVs.

- Slurry samples (7-day cores)

  - Blanks--No analytes were detected in the reagent blanks.

  - Spiked samples--Matrix and surrogate spike recoveries were within the acceptance limits. Recovery of toluene was above the acceptance limits, but impact on the overall results should not be significant.

  - Duplicate samples--Duplicate samples analyzed for VOC by Method 8240 were within accuracy acceptance limits.

- Slurry sample leachates

  - Blanks--No metals or PCBs were detected. Acetone was detected in some of the blanks, but since this is not a field contaminant and the levels were so low, the effect on the results is negligible.

  - Spike samples--Metals recoveries for the nine samples were all acceptable. Matrix spike and surrogate spike recoveries for five VOCs were good although a few examples of deviation from the acceptance range were noted. For PCBs the recoveries were low, indicating detection limits may be higher than reported. However, no PCBs were detected in the leachates.

  - Duplicates--All metals and volatile organics met the acceptance criteria on coefficient of variation.

- Core samples and core sample leachates

  - Blanks--Chromium, lead, copper, and zinc were detected in reagent blanks. However, review of the field data shows that the low levels of the analytes make these values insignificant. Eight VOCs were detected in 1 or 2 of 10 laboratory reagent blanks; therefore low levels of those compounds must be reviewed with some suspicion since toluene, xylene, and ethyl benzene, three of the five measurable components of VOCs, are included. PCBs were not detected in the blank. Some phthalates were detected, but may be laboratory contaminants.

  - Spiked samples--Ten spiked samples for metals were all within acceptance limits of 80-120%. Eight spiked samples for VOC were performed and virtually all results were within acceptance limits. All BNA spikes met acceptance limits.

  - Duplicate samples--Results for metals and VOC were very good, within a CV of 10%.

  - BNA analyses--The high results for phthalates levels in blanks and low naphthalene in the matrix spikes may provide cause for suspicion. However, phthalates are a common laboratory contaminant and low levels in field samples may be an error. An interlaboratory performance audit by Radian also left suspicions on the phthalates results. The spiked sample results for phenols met acceptance criteria.

From the above results for blanks, spikes, and duplicates, the chemical analyses should be acceptable. The primary purpose of the analyses is to observe changes and orders of magnitude of the values before and after the HAZCON treatment. The deviations noted above should have an insignificant impact.

The physical tests, moisture, bulk density, and unconfined compressive strength were performed in triplicate for each sample collected. The other physical tests, permeability, particles size, and pH, were performed only once on each sample. Permeability is the most important parameter of the tests performed once. The results showed all the treated soil permeabilities were in the 10^{-8} to 10^{-9} cm/sec range, which is very low. Exact numerical values and differences between samples is less important than the observed consistency of the order of magnitude results.

The QAPP did not include any protocols for the microstructural analyses, which were performed by Scientific Waste Strategies. Since these results are only intended to be qualitative and no attempt was made to quantify, the trends reported should be valid.

SECTION 8

DISCUSSION OF RESULTS

The analytical results summarized in Section 7.0, are discussed and evaluated in Section 8.1. Operating procedures, a chronology of which is presented in Section 5.2 for the HAZCON Demonstration Test, are evaluated in Section 8.2

8.1 ANALYTICAL RESULTS

The analytical data consist of physical test results of untreated soil, treated soil after a nominal 7-day curing period, and essentially fully cured samples, which were analyzed more than 28 days after treatment. The discussion of the analytical results can be further subdivided into the following:

- Physical tests
- Chemical analysis - primarily soil composition and leachate results
- Microstructural analyses
- Overall evaluation

8.1.1 PHYSICAL TESTS

The physical tests on the soil and cores consisted of the following:

- Free moisture - untreated, 7-day, 28-day
- Undisturbed bulk density - untreated, 7-day, 28-day
- Particle size distribution - untreated
- Permeability - untreated, 7-day, 28-day
- Unconfined compressive strength - 7-day, 28-day
- Total organic carbon - untreated
- Oil and grease - untreated, 28-day
- pH - untreated soil
- Wet/dry weathering - 28-day
- Freeze/thaw weathering - 28-day
- Unconfined compressive strength after weathering - 28-day

8.1.1.1 BULK DENSITY

The treated soil density was about 10-20% greater on average than the undisturbed untreated soils. The bulk density test for all samples was performed in triplicate. In general, except for the untreated soil in DSA, the individual area results were in tight bands, with a bulk density greater than 1.4 mg/l particularly for the treated soils. For FSA, the treated soil results were 5% lower than the untreated soil results. Results of the microstructural analysis presented in Section 7.2.3 indicate a very porous structure for all the 7- and 28-day cores, which may account in part for the relatively small bulk density increases.

The bulk density did not change between 7 and 28 days; the change occurred entirely in the initial 7-day period. Density decreased with higher oil and grease content, both for the untreated and treated soils. Since the soil represents only about 40% of the total weight of the mix of soil, cement, water, and Chloranan, and the bulk density increase is 10-20%, the volume of the treated soil more than doubles. Calculations for volume increase for each plant area is provided in Appendix D.

The laboratory-prepared solidified formulations on soils from LAN and FSA, without the use of Chloranan, showed a lower bulk density than the field samples, particularly for FSA. For FSA the bulk density was reduced from 1.51 to 1.36 mg/l. Two possible contributory causes may be the lack of Chloranan or the higher moisture content.

8.1.1.2 FREE MOISTURE

The water addition during processing was not tightly controlled or adjusted for moisture in the feed. The water was adjusted by HAZCON based upon visual observation of the slump of the concrete mix. Based upon the material balances shown in Table 5.2, the total water added per run is the correct order of magnitude, 40% by wt. of cement. Comparing the untreated soil with 7-day treated soil showed an increase in free moisture content. Comparing the 7-day material to 28-day showed that, except for DSA, the moisture content decreased by about 10-15%. This is probably due to the continuation of the cement hydration reactions, which would reduce free moisture (drying at $60^{o}C$). It appears that the hydration reactions are 60-80% complete at 7 days, with DSA and LAS close to 100% complete.

8.1.1.3 PERMEABILITY

The permeabilities of the treated soils were very low, primarily in the range of 10^{-8} to 10^{-9} cm/sec. This compares to undisturbed soil permeabilities of about 10^{-1} to 10^{-2} cm/sec, except LAS, which was near 10^{-5} cm/sec. Calculations for the permeability reduction factors are provided in Appendix D. The permeability for the laboratory formulations without the use of Chloranan were a factor of 10 greater than field cores for LAN and equivalent to the field cores for FSA. The untreated filter sludge was impermeable, and the scheduled tests could not be performed. In general, for stabilization/ solidification processes, 10^{-7} cm/sec is considered impermeable. The design of soil barrier liners for waste disposal sites target permeabilities of 10^{-7} cm/sec or less. The permeability for the two laboratory formulations on LAN and FSA, without the use of Chloranan, provided results that were a factor of 10 greater for LAN and equivalent for FSA to the field cores. There were not any differences between the nominal 7- and 28-day core sample permeabilities. This is due to the fact that the 7-day as well as the 28-day permeability tests were run after curing for 30+ days. The permeability measurements were very time-consuming, and difficulties were encountered in performing the analyses. Therefore, they could not be performed in the time frame originally planned. Tables A-14 and A-23 in Appendix B provide all the permeability results and the dates on which the tests were performed.

8.1.1.4 UNCONFINED COMPRESSIVE STRENGTH

The unconfined compressive strength test, which for each sample was performed in triplicate, produced individual values that ranged from about 100 psi for FSA to above 2200 psi for DSA. Based upon the averages of the three tests, the range was from 220 psi at FSA to 1570 psi at PFA, both at 28 days. In general, compressive strength was markedly lower with increased oil and grease (O&G). The average of triplicate tests at 28 days for the two highest oil and grease areas was about 220 psi for FSA (25.3% O&G) and 520 psi for LAN (16.5% O&G).

Decreasing pH with increased O&G is believed to be a result of the oil and grease concentrations and not a factor in the unconfined compressive strengths. The soil particle size distribution may influence core strengths, but insufficient data exists to confirm. In addition, with the exception of PFA, which was a litter coarser, the particle size distributions were equivalent.

Although it was expected that the 28-day sample tests would give higher strengths, this was not evident from the results. The free water levels discussed above indicate that the cement hydration reactions were still proceeding, which should have resulted in increased strengths. It appears that LAN and PFA did increase in strength, but that the others either decreased or remained unchanged. An explanation for this unexpected lack of strength increase is not available.

For the laboratory formulation tests on FSA and LAN, definite increases in strength between 7- and 28-day cores of 30-50% were observed. These formulations for LAN obtained 7- and 28-day core strengths comparable to the field blocks. However, for FSA, the field blocks were many times stronger. This seems to confirm that the Chloranan helped the solidification process. At lower oil and grease levels, the effect of Chloranan may be less significant.

8.1.1.5 OIL AND GREASE

Oil and grease levels ranged from about one percent by weight for DSA to 25% for FSA. Typically the total organic carbon (TOC) level is about 4-5% greater than the level of O&G, which is as expected. The values for O&G reported for the screening samples are consistently greater than for the feedstocks used in the Program. This probably can be explained by the method of obtaining each feedstock for the Demonstration Test, where a backhoe was used; some less-contaminated soil was excavated along with the more-contaminated soils. For the screening samples, the most contaminated area in each plant location was targeted and only a 40 lb sample was collected.

8.1.1.6 pH

In general, the feedstocks were acidic, except for PFA. Values as low as a pH = 2.4 were obtained for FSA samples. There is some trend toward lower pH values with increased oil and grease levels. However, the original source of the contamination would also have an impact, not just the quantity.

8.1.1.7 PARTICLE SIZE

Particle size distributions on the untreated soils were also measured, except for FSA, which was too sticky for the screening analyses. Basically the soils are fine, with about half the soil by weight finer than 200 mesh (74 micron). PFA was somewhat coarser than the other soils.

8.1.1.8 WEATHERING

The two weathering tests, wet/dry and freeze/thaw, are twelve-cycle tests, measuring weight loss relative to a control specimen. The control specimen is maintained at 72°F in a moisture chamber, when the test specimens are dried or frozen for 24 hrs. Both samples then are inserted into water and placed in the moisture chamber for 24 hrs. The results of samples from each site location for the wet/dry tests indicate that the weight loss of the test specimens is only slightly greater than for the control. However, the loss differentials during the freeze/thaw tests appear to be larger. All weight losses were about one percent for both the specimens and controls.

Unconfined compressive strengths on both the test and control specimens were run. The results for the test samples show that compressive strength was not lost in either the test specimens or controls.

8.1.1.9 OTHER OBSERVATIONS

Significant variations in physical properties of the soil between each composite within a soil area were noted. For example, oil and grease at LAS ranged from 6.1% to 8.6% and for LAN from 14% to 18%. Moisture levels were also somewhat variable at FSA, LAS, and LFA. This means that individual grab samples within a given feedstock are even more variable. Thus, physical test results on untreated soil based on average feed properties may not be directly related to the 7-day and 28-day core sample results, which are based more on localized properties of the solidified soil samples. Although it is believed that the overall results are representative for each plant area, individual distortions in the data do exist.

In addition, significant variations even within a sample, split spoon or core, probably exist. Many of the leaching tests (see Appendix D) showed a larger weight of an analyte or organics group existed in the leachate than in the solid. Also, consistent material balances for the lead and organic analytes between treated and untreated soil could not be obtained from the data. Only for total oil and grease was there a consistency in the concentrations before and after treatment. However, due to the large amount of data available, definitive trends in the results exist. Therefore, the results obtained are still valid.

The laboratory formulations were prepared without Chloranan, similar to the method concrete is typically blended. For FSA, the UCS test values were about one-tenth of those for samples collected in the field. In addition, the bulk density was lower by almost 10%. Results for the other laboratory prepared samples were equivalent to the field prepared and cured samples. Thus, Chloranan improved the physical properties of a treated soil where the oil and grease levels were high, about 25% by wt in the untreated soil.

A grab sample of the process water showed low suspended and dissolved solids, with a pH of 8.05. This water should not impact the process or any of the laboratory analyses.

8.1.2 CHEMICAL ANALYSES

The chemical analyses consist of the following:

- Untreated and treated soil compositions
- TCLP leachate analyses
- Special leach test analyses

A discussion of the results highlighted in Section 7.2.2 follows.

8.1.2.1 SOIL COMPOSITION

The composition of the untreated soil was basically as expected. The oil and grease values were a little low compared to the values anticipated based upon the screening samples and the RI/FS prepared by NUS Corporation for EPA Region III. This probably is due to the inclusion of less-contaminated soil around and below the targeted soil and to the general variability within each area. Samples having the maximum oil and grease in each of the six plant areas were targeted for the screening samples.

The PCB concentration levels, with averaged values up to 52 ppm at LAS, were higher than originally anticipated based upon the RI/FS and screening samples, which were at less than 25 ppm. The two Aroclors detected were the same as measured in the screening samples, but both were at higher concentrations.

The results for the priority pollutant metals were as expected. Lead was the major contaminant with concentrations up to 2.3% by wt. measured. After reviewing the soil analyses, only the major metal contaminants were carried forward to analyze in the 28-day cores and leachates. These were chromium, nickel, zinc, copper, and cadmium. In general the levels of contamination in the soil agreed with those obtained during the screening tests.

The results for the base neutral/acid extractable (BNAs) showed primarily phthalates, phenols, and naphthalene. Phenols differ from other BNAs in that they have greater solubility in water and therefore, may be more readily leachable. Other BNAs reported in the RI/FS but not detected in the screening analyses, such as fluorene, pyrene, and fluoranthene, were only occasionally detected in these analyses. The phenols were not checked for on the screening samples. Phthalate concentrations in the 28-day core samples (ND to 2.15 mg/kg) were very low compared to the untreated soil (12.15 to 34.2 mg/kg). This may be caused by base-catalyzed hydrolysis reactions, which is a reasonable possibility, or possibly other reactions caused by the Chloranan.

The volatiles in the FSA samples were considerably greater than anticipated, averaging 150 ppm by wt. It had not been expected to observe volatile levels above 30 ppm for any of the plant areas. The screening test results showed LAS to have the highest concentration of volatiles, with much less reported for any of the other plant areas. For LFA, PFA, and DSA, toluene was injected into the slurry mix to produce a final concentration of 125 ppm by wt., based upon the feed soil. The maximum value reported in the core samples was 24 ppm in 28-day cores at LFA, with values down to 1 ppm. Since the soil is only 40% of the total core weight, this maximum value is equivalent to 60 ppm on a soil weight basis. Therefore, the majority of the toluene was lost. This indicates that the toluene either vaporized off in the HAZCON mixing screw, possibly due to poor injection or improper mixing, or during sample preparation in the pulverization step, or both. However, sufficient toluene remained to provide valuable information for leaching test analyses.

Attempts to relate VOC and BNA component concentrations before and after solidification were not successful. There was such variability in the grab samples that in some cases it appeared that concentrations were greater in the cores than in the untreated soil. However, for oil and grease, approximate material balances could be obtained; see Tables 7.1-7.6.

8.1.2.2 TCLP LEACHATE ANALYSES

Oil and grease in the leachates from the untreated soils were near the detection limit of 0.2 ppm by wt. in the range of <0.2 ppm at DSA to 3.7 ppm at FSA. These results are lower for each plant area than for the 7- and 28-day core leachates, where the results were in the range of 1-10 ppm by wt. (mostly 2-4 ppm by wt.). Since these values are all so close to the detection limits for the laboratory procedure, it may not be proper to differentiate between them. However, it is also possible that the treatment process tended to agglomerate the oil and grease and after crushing the solid core for performing the leach test, some O&G globules were released into the leachate. The leachate concentrations for the special leach tests were less than for TCLP. Also, the oil and grease concentrations in the treated cores are about 40% of these of the untreated soils.

The immobilizing of the priority pollutant metals was accomplished by the solidification. Except for lead and zinc, virtually all the metals were reduced to their detection limits in water. For lead the values were just above detection limits, ranging up to 400 ug/l, which is well below regulatory levels of about 5 ppm by wt. However, lead was the predominant metal contaminant with measured soil concentrations ranging from 0.3 to 2.3% by wt., so the lead reduction was dramatic.

Except for phenols, the BNAs (semivolatile organics) were reduced to near their detection limits of 10 ug/l in the leachates of both untreated and treated soil samples. This is a reduction of more than one thousandfold, compared to the contaminated soil. However, the phenols were not reduced to the same extent. For LAN and FSA, with concentrations in the soil or cores ranging from 5-400 ppm by wt., the reduction factor is of the order of 10-100. For FSA, TCLP leachate concentrations of 3-4 mg/l were observed for both treated and untreated soils. Therefore, the HAZCON process did not appear to reduce the leachability of phenols. Results of the MCC-1P and ANS 16.1 leach tests provided equivalent results. In addition, the quantity of phenols in the leachate increased with time.

The volatiles in the leachates ranged from 100 to 1000 micrograms per liter (for the higher soil and core concentrations). These are reduction factors of about 100 on average compared to the soil. However, the concentrations in the untreated soil, 7-, and 28-day core leachates are approximately the same. Therefore, at least in the concentration range investigated, up to 150 ppm by wt. (FSA), the solidification did not appear to impact the leachate results. The results of the special leach tests showed leachate concentrations less than for TCLP leachates, and the concentrations did not appear to be time-dependent.

Calculations for total VOCs, toluene, total BNAs, phenols, and lead showed in many instances, except for lead, greater quantities of the analyte(s) in the leachate than in the soil. This indicates that great variability in the concentration of these analytes may exist within a given sample. Concentrations in the test specimens used for the three leach tests were possibly much greater than in the material used for determining concentration levels in the total samples. This could also account for, in some cases, the greater migration potential (leaching potential) of the organic analytes in the treated soil compared to that in the untreated soil, even though average concentrations of the analytes in the cores are less than one-half those in the untreated soil. However, since many leaching analyses have been performed, the general observations for organics, that the leachate concentrations for the treated soils are about the same as the untreated soil, is valid.

The special leach tests, MCC-1P and ANS 16.1, were performed on one sample set taken from 28-day cores for LAN, FSA, PFA, and LAS. In general, for a given time frame, the results from MCC-1P were greater than from ANS 16.1, which may be due to MCC-1P being performed at 40°C vs. ambient conditions for ANS 16.1.

The MCC-1P leachate concentrations for VOC and BNAs were equivalent to TCLP extracts. For lead the values were greater and increased with leach time. For oil and grease, the TCLP, MCC-1P, and ANS 16.1 leachate concentrations appear equal.

A brief comparison test between EP Tox and TCLP for metals was performed on samples from LAN and FSA. The results for EP Tox were greater for LAN and about the same for FSA. This is expected for basic solutions (these leachates are basic due to the cement components).

8.1.2.3 SPECIAL LEACH TEST ANALYSES

Leach tests ANS 16.1 and MCC-1P were two procedures originally developed for the nuclear industry for the leaching of low level radioactive wastes, but have been applied with modifications to hazardous wastes. These tests utilized solid cores simulating the solidified wastes, as compared to TCLP and EP Tox where the solid cores are first ground to a powder. MCC-1P simulates a relatively static groundwater flow, with the samples in contact with one leachate for time periods of 3, 7, 14, and 28 days at a temperature of 40°C. ANS 16.1 simulates a moving groundwater regime with the solid core specimen placed in a new fresh leachate, so that the boundary concentrations of the analytes are kept below saturation level. Samples are collected after 1, 3, 7, 14 days with the total leach time being 28 days. A diffusion coefficient might then be calculated.

It should be noted that experience with these tests on hazardous wastes is limited. Comparisons to the treated soil TCLP results have been made, but the significance of the differences is unclear. Some differences would be expected due to the diverse ratios of solid to extract used in each test. The nature of these two procedures, that of simulating leaching from a solidified mass, makes it illogical to perform these tests on untreated soils. Therefore, the results of these tests are compared to the treated soil TCLP tests only.

It was anticipated that TCLP would be the most severe leaching test, providing the highest contaminant concentrations in the extracts. However, the extract concentrations for the metals for MCC-1P were greater than for TCLP, 0.3-0.7 mg/l versus 0.01-0.06 mg/l, and approximately equivalent for VOCs, BNAs, and oil and grease. This indicates that at least for the 28-day cores from the HAZCON process the increased surface area for leaching for the TCLP test is balanced by the increased time and temperature of MCC-1P. The differences between MCC-1P and ANS 16.1 extracts may be due to the higher leaching temperature, 40°C versus 22°C.

Since the leaching times range from 1 to 28 days in these tests, the effect of time was reviewed. For the organics, time did not appear to be related to leachate concentrations except for phenols in the MCC-1P test. Since phenols are soluble in water, this is not unexpected. The concentration of lead appears to increase with time for both leach tests, although the trend for MCC-1P is less definitive.

8.1.3 MICROSTRUCTURAL STUDIES

Microstructural and microchemical analyses are proven methods for understanding the mechanisms of structural degradation in materials similar to those in this Demonstration Test. The literature is replete with examples of SEM and XRD analyses of soils, cement, soil-cement mixtures, and each of these mixed with various inorganic and organic compounds. However, there have been relatively few studies of the microstructure of complex waste/soil mixtures like those resulting from stabilization/solidification procedures. Consequently, in some cases interpretation of microstructural observations may be difficult. The microstructual report is intended to be complete in its reporting, yet conservative in its conclusions. Many observations will become more useful as the understanding of stabilization/solidification technologies improve.

A discussion of the results presented in Section 7.2.3 follows:

- The two predominant clays seen in the samples, illite and kaolinite, are nonexpandable clays. Therefore, the organic compounds in the soil will not be adsorbed within the layers of the clay minerals. Any organics adsorbed will be on the outside surface and therefore will be more loosely held.

- The crystalline phases seen in the core samples, portlandite, ettringite, calcium silicates, calcium aluminate, and gypsum, are the principal components of portland cement. Portlandite and ettringite are the major hydration phases of portland cement. Thus, the major bonding agent is portland cement, and SEM observations agree with this conclusion.

- An abundance of pores of all sizes and shapes were observed in the core samples. Some of the pores were due to trapped air bubbles. The high concentration of the pores may be due to incomplete mixing. Crystals of portlandite, calcium aluminate hydrate, and ettringite grew into these pores. These crystals are thus more easily accessible to percolating water.

- The quantities of unhydrated tricalcium silicate and dicalcium silicate were much greater than usually observed in hydrated portland cement with moderate water-to-cement ratios. The water-to-cement ratio of 0.4, typical of cement, is used in the processing operation. The high concentration of unhydrated silicates could result from inefficient mixing, resulting in insufficient water transported to these grains.

- Mixing does not appear to be highly efficient. Among the facts indicating this are: 1) the brownish aggregates do not undergo disaggregation 2) there are significant amounts of unhydrated Portland cement clinker in the samples, 3) there are globules of dark colored material in the core samples visible to the naked eye, and 4) there are many pores, including air bubbles.

- Two factors suggest that soil components passed through the process unchanged. They are the presence in the cores of apparently unaltered brownish aggregates and peaks in the x-ray diffraction pattern for both the soil and the cores, which could not be identified with any expected mineral constituents of the soil.

In summary, some of the waste in the soil appears to pass through the process unaltered, and thus, it appears that encapsulation is a major part of the mechanism of solidification/stabilization. In addition, the mixing operation is not highly efficient, resulting in incomplete hydration of the cement and high porosity.

8.2 OPERATIONS

For the 5-cu-yd test runs, HAZCON utilized four people to operate the unit. Their functions were as follows:

- 1 man - add feed soil and water to feed hopper
- 2 men - move and watch slurry mixer, smooth surface of blocks, and control Chloranan flow
- 1 man - at the control panel and supervise operations

In addition, EPA provided support services to excavate the feedstock, screen it, and bring it to the HAZCON MFU. The soil was brought to the unit in a 2 1/4 cu yd (soil level to surface of bucket) front-end loader, which fed it very slowly to the feed hopper at approximately the rate the MFU processed it. Therefore, at least two support people were required full time to provide feed to the HAZCON unit. Also a cement supply truck with operator/driver was on hand full time. For the 25-cu-yd run, three additional people were required to operate the cement pump and control the feed to the large pits.

Some operating difficulties were encountered in all of the runs, causing down times on the order of one minute to two hours. The shutdown periods related to momentary screw pluggages due to lack of water, oversized feedstock (stones greater than 3 inches), interruptions of Chloranan feed, or emptying of the cement feed hopper, which required refilling from a supply truck. For two runs, DSA and PFA, only four blocks were prepared due to a combination of lack of daylight, need for more feed, and operating difficulties. On two occasions the soil feed screw jammed so badly that the MFU had to be brought to the decontamination area for a complete clean out. Direct addition of water by hose to the feed screw facilitated the movement of the soil and reduced the likelihood of jamming. This was a water feed stream that was not measured directly by the in-line flowmeter. Only approximate consumptions could be provided.

In generally observing the operations, the consistency of the slurry was quite variable due to variations in water feedrate. The consistency of the mixed product varied from a very thin slurry to almost a dry powder. In addition, the variability of the slurry mix may have prevented the Chloranan from achieving its fully claimed benefit in counteracting the presence of organics. As indicated in Section 8.1.3, if insufficient water is provided, components of the cement, such as the tricalcium silicate was incompletely hydrate, as observed in the x-ray diffraction analyses. This will result in a weaker and less durable block, as compared to a block from fully mixed components.

A review of the material balances shows that for the 5-cu-yd runs, the total mass of the blocks was consistent with the calibrated rates for cement and soil adjusting for outage time. Material balances also indicate the following:

- The soil was only 40% of the total weight of the blocks.
- The cement-to-feed ratio was approximately 1:1.
- The Chloranan-to-feed ratio on a weight basis ranged from 0.05 to 0.09, which is less than the target value of 0.1. The lowest value was for FSA. No apparent reduction in physical properties were observed.
- The water-to-feed ratio was approximately 0.4 on a weight basis, which is appropriate for concrete preparation.
- The volume of undisturbed feedstock to produce the 5 cu yd of slurry to fill the five 1-cu-yd molds was approximately 2 cu yd. (The front-end loader held 2 1/4 cu yd, filled level to the top of the bucket, which produced 4 to 5 blocks.) The approximate bulk density of the screened soil after transporting to the unit was about 20-30% less than in the undisturbed samples analyzed and reported in Tables 7.1-7.6.

For the extended length run at LAS, approximately 22-24 cu yd of slurry was produced to fill the three 1-cu-yd molds and the two large excavations. The excavations were 8x16 ft and were filled to a depth of 2-2 1/4 ft. As shown in Table 5.1, approximately 52,300 lbs of the total feed (soil + cement + Chloranan + water) was used. However, based upon the bulk density of solidified soil of 1.7 g/ml (106 lbs/ft^3), for the total weight processed only about 18 cu yd of slurry would have been produced. Therefore, it appears that 10,000-15,000 lb more total feed material was processed. Since the cement and water rates are constantly measured and the soil is based upon the initial calibration, it is quite likely that the missing mass, compared to the HAZCON Monitoring Worksheet, is contaminated soil. Six front-end loader loads of soil were processed, which is approximately 13-14 cu yd. If the screened feed soil had a bulk density of 1.2-1.3 g/ml (75-80 lb/ft^3), this would indicate a total soil usage of about 30,000 lb, which is over 10,000 lb greater than that recorded on the HAZCON Monitoring Worksheet, thus providing sufficient feed to fill the pits.

Also shown on the Monitoring Worksheet, two-thirds of the cement was used before starting the slurry flow to the second large pit; this value should have been only slightly more than 50%. This ratio tended to be confirmed by the fact that 130 of a total of 255 gallons of Chloranan was used only 10 minutes after the second large pit was started.

Based upon this reasoning, the overall ratio of cement-to-soil was about 2:3 and probably even lower for the second large pit. In addition, the Chloranan-to-soil feed rate is about 0.08 versus that listed in Table 5.2, 0.119, which is based upon the HAZCON Monitoring Worksheet. It does not appear that any loss in physical properties resulted from this apparent reduction in cement feed. (See Appendix B, Table A-14.)

8.3 MEETING OF SITE PROGRAM OBJECTIVES

Information relating to each of the program objectives in Section 1.2 was obtained. This information can be summarized as follows:

- Immobilization of site contaminants--The priority pollutant metals were very satisfactorily immobilized, with leachate concentrations reduced to below 0.1 ug/l for soils containing metals up to 23,000 mg/kg. Untreated soil extract concentrations were typically 20 to 50 mg/l. Immobilization of organics, VOCs, BNAs, and PCBs was not observed. TCLP leachate concentrations for organics in untreated and treated soils were approximately equal. This occurred even though, on average, the treated soil composition is lower in contaminants, due to the addition of cement, water, and Chloranan.

- Technology effectiveness as a function of oil and grease concentrations--The soil samples taken were in the range of 1-25% by wt. oil and grease (O&G). Higher O&G soils tended to have more VOCs and BNAs. Greater VOCs and phenols (BNA components) led to higher leachate concentrations. The most direct impact of higher O&G is reduced unconfined compressive strength. In addition, FSA, which had the greatest O&G content, appeared to have a slightly greater permeability than the other test samples.

- System performance--The operational performance of the system was erratic, with many short and long shutdowns. The system shutdowns ranged from 1-2 minutes up to 2-3 hours. Many shutdowns occurred for each soil feedstock. The slurry consistency was quite variable, ranging from a powdery mix to a very thin slurry. However, for the extended duration run, operation outages were less and the consistency of the product slurry improved. The impact of consistency on physical or chemical properties of the solidified blocks was not observed.

- Long-term integrity--Measurements of long-term integrity of the solidified masses cannot be directly performed. However, indications of potential difficulties could be inferred from the microstructural analyses. These observations showed a porous structure, with incomplete cement hydration and organic globules existing in the solidified cores.

- Remediation costs--Remediation costs were prepared based upon using HAZCON's MFU and the operating conditions used for the Demonstration Test. The results showed that the cleanup cost was $205 per ton of contaminated soil under the ground rules defined.

SECTION 9

ECONOMICS

9.1 INTRODUCTION

A cost analysis addresses two main categories, capital costs and operating and maintenance costs.

Capital costs include both depreciable and nondepreciable cost elements. Depreciable costs include direct costs for site development, capital equipment, and equipment installation as well as indirect costs for engineering services prior to unit construction, such as feasibility studies and consultant costs, administrative tasks such as permitting, construction overhead and fee, and contingencies. Nondepreciable costs include start-up costs including operator training, trial or test run expenses, and working capital. Operating and maintenance costs include variable, semivariable and fixed cost elements. Variable operating cost elements include raw materials, utilities, and residual water disposal costs. Semivariable costs include unit labor and maintenance costs, and laboratory analyses. Fixed costs include depreciation, insurance, and taxes.

The above cost element breakdown, however, is based upon a permanently sited hazardous waste cleanup device. The HAZCON MFU as employed at the Douglassville Superfund site is a transportable unit that will not be installed at a fixed site. Thus, it assumes some different cost elements that will impact on a cost analysis from the more frequently encountered permanent installations.

In general, the cost for a transportable hazardous waste remediation facility falls into three categories: capital costs including all costs that can be amortized over the service life of the unit; mobilization/demobilization costs associated with start-up and shutdown at a given site, that can be amortized over the duration at the site; and operating cost to operate and maintain the system. Capital costs can be subdivided into direct, indirect, and nondepreciable cost elements. Mobilization/demobilization costs can be accrued as semivariable operating and maintenance costs. Operating costs include variable utility and raw material costs, semivariable labor and maintenance costs, and fixed costs such as depreciation, insurance, and taxes.

In addition, for a mobile unit, several capital cost elements defined for the permanently sited unit should be redefined into a different cost element category. These include the direct costs for site development and the direct costs for engineering studies, which on a site-specific basis become mobilization/demobilization costs. These factors are not included here because of the complexity of the analysis and planning in this area. Total site cleanup is the responsibility of others, with the HAZCON technology used for only part of the total remediation.

Based on the above, an overall cost element breakdown, as illustrated in Table 9.1, can be developed.

9.2 COST ELEMENTS

A detailed discussion of each of the cost elements defined in Table 9.1 is provided in the following subsections. Since this cost analysis is being prepared based upon the Demonstration Test, the cost to process each ton of contaminated soil will be distorted to a greater value. Cost projections for a commercial installation will be included in the Applications Analysis Report. In addition, not every expense that might be encountered in a site cleanup is included. Items such as permitting and site preparation were omitted due to their complexity to predict costs.

9.2.1 CAPITAL COSTS

9.2.1.1 DIRECT COSTS

Equipment Fabrication/Construction and/or Purchase --

The costs for the design, engineering, materials and equipment procurement, fabrication and installation of the HAZCON MFU (including vehicle), are included as direct costs. The costs include all the subsystems and components installed but do not include the costs of the vehicles for the transport of the accessory equipment, described in Section 3.2. Waste preparation equipment is not included as it can be assumed to be rented or provided by the site-responsible party. Pretreatment or posttreatment of the soil is assumed not to be required. For the items calculated as a fraction of direct costs, the total of the HAZCON MFU and associated tanks, pumps, etc., is the capital cost value used.

The capital cost value of the MFU was provided by HAZCON and is $100,000. It is assumed that the equipment has a 10 yr life. In addition, storage bins or tanks for cement, Chloranan, and fuel are required, as well as an air blower for transferring cement, pumps for the liquid, and associated piping and controls. This was assumed to be an $80,000 cost to the project, whether the equipment was purchased new or used or it was sold or discarded at project completion. These factors are site specific and major variations could occur between sites.

9.2.1.2 INDIRECT COSTS

Administrative/Permitting --

Administrative costs associated with regulatory compliance issues could be numerous and varied. The costs that are being accrued under this cost element are directed to the overall non-site-related regulatory activities in establishing federal and state permit requirements, preparing initial permit applications, and supporting permit application information throughout the permit issuance process. Once the final permits are issued, recordkeeping, inspection, survey response to permitting agencies, and additional reporting activities may be required. These costs include the preparation of technical support data, sampling/analysis, and quality assurance project plans by in-house engineering personnel, RCRA/TSCA permit forms (if applicable); time, travel, and per diem for consultant and in-house staff interfacing with Federal EPA officials; and in-house administrative and clerical staff. For the cost estimates developed in this analysis, these factors are not included.

For this cost analysis, administration costs are taken as 10% of direct costs (HAZCON MFU and tanks, pumps, etc.) on an annual basis. It includes office expenses such as supplies, telephones, reproduction equipment, and furniture, but not salaries (included elsewhere).

Contingency --

A contingency cost, approximating 10% of the direct capital cost on an annual basis, is allowed for unforeseen or poorly defined cost definitions. For the HAZCON process this is a minor factor.

9.2.1.3 NONDEPRECIABLE COSTS

Operations Procedures/Training --

In order to ensure the safe, economical, and efficient operation of the unit, the creation of operating procedures and a program to train operators is necessary. Costs that may accrue include: preparation of a unit health/safety and operating manual, development and implementation of an operator training program, equipment decontamination procedures, and reporting procedures. These documents must be site-specific. They can be related to basic documents, the preparation costs for which can be amortized over the life of the equipment.

TABLE 9.1. COST ELEMENT BREAKDOWN

CAPITAL COST

Direct

- Equipment Fabrication/Construction or Purchase

Indirect

- Administrative/Permitting
- Contingency

Nondepreciable

- Operations Procedures/Training
- Initial Start-up/Shakedown
- Working Capital

OPERATING & MAINTENANCE COSTS

Variable

- Raw Materials - Cement
- Fuel
- Power
- Water
- Chemicals - Chloranan

Semivariable

- Labor
- Maintenance
- Equipment Rentals and Consumables
- Analytical Services
- Mobilization/Demobilization

    Site Preparation/Logistics
    Transportation/Setup
    On-Site Checkout
    Working Capital
    Decontamination/Demobilization

Fixed

- Depreciation
- Insurance
- Taxes

It was assumed that three days of training would be required for all HAZCON personnel, site support personnel, health and safety officer, and sampling technician. The cost includes salaries and living expenses. These are the only costs included in this category.

Initial Start-up/Shakedown --

After the unit is brought to a site it must be initially started and operated to check out the mechanical and technical integrity of the equipment and its controls. This cost is assumed as part of site mobilization.

Working Capital --

Although the unit is a transportable system, it will require a supply of maintenance materials attributable to a nondepreciable capital cost. Maintenance materials account for approximately one-half of the total maintenance cost, and 3-month inventories are usually maintained. This cost as used in Table 9.2 is assumed as 10% of maintenance costs.

9.2.2 OPERATING & MAINTENANCE COSTS

9.2.2.1 VARIABLE COSTS

Variable operating cost elements for this unit include fuel, power, water, chemicals, and process waste disposal. They are defined as variable operating cost elements because they can usually be expressed in terms of dollars-per-unit flow of soil treated and as such, these costs are more or less proportional to overall facility utilization during specific site operations. It is also assumed for the tabulation of costs that there are no process waste byproducts.

Fuel --

The fuel requirement for the unit includes diesel fuel to power the vehicle part of the MFU. In addition, fuel is used for supporting vehicles - backhoe, front-end loader, etc. It is estimated by HAZCON that their equipment will consume 4 gph. It is assumed that the supporting equipment consumes an additional 4 gph. The cost of diesel fuel is about $1.00/gal.

Power --

The power requirement for the unit includes the electrical requirements for the trailers, sampling equipment, auxiliary lighting, etc. It is assumed that the daily average power consumption is 5 kw with the cost of electricity $0.04/kwhr.

Water --

Water use is based upon the water content of the feedstock to bring the cement-like final slurry to about 20% by wt. water. In addition, some water is used for decontamination. The total average water usage rate is 14 gpm at a cost of $0.80 per 1000 gallons.

Chemicals --

The HAZCON proprietary additive is Chloranan, which inhibits the effects organics have on the solidification of cement. It is utilized in a ratio to the contaminated soil of 1:10. HAZCON indicates the delivered cost for cement is $50/ton and Chloranan is $3.00/gal (Chloranan density is 9.0 lbs/gal).

Decontamination Water --

If the unit is not operated 24 hours per day, the unit needs to be cleaned with high pressure water or steam to prevent plugging. Costs will accrue for the containment and disposal of this waste stream. An additional 10% water consumption was assumed.

9.2.2.2 SEMIVARIABLE COSTS

Labor --

Operating costs for personnel for the HAZCON unit is based upon 3 shifts per day, 21 shifts per week and totals 17 people; this includes 12 process operators, 4 supervisors, and 1 overall coordinator. In addition, there are support personnel for operating the contaminated soil moving equipment, a site safety and health office, the project manager, office personnel, and a part-time sampling technician. This totals 21 people.

The labor and living expenses for the HAZCON personnel was provided by HAZCON. These costs range form $17.50/hr to $50/hr for salaries with overhead and $85/day for expenses. The support personnel costs were based upon actual costs incurred by EPA/Enviresponse for the Demonstration Test. Salaries with overhead range from $20 to $60/hr with living expenses (except local hires) at $120/day.

Maintenance --

Maintenance materials and labor costs are extremely difficult to estimate and cannot be predicted as functions of a few simple waste and facility design characteristics because a myriad of site-specific factors can dramatically affect maintenance requirements. Annual maintenance cost will be assumed as 10% of capital cost.

Analyses --

In order to ensure that the unit is operating efficiently and meeting environmental standards, a program for continuously analyzing waste feed and treated solids is required. Initially sample sets will be taken daily, and less often as operation efficiency improves, approximately once per week. based upon the expected need to perform many of the laboratory tests described for the Demonstration Test, the cost of a sample set is estimated to be $5000.

Mobilization/Demobilization --

As discussed in Section 9.1, the following costs will accrue to the HAZCON unit at each specific site. The costs are site-specific and may vary widely depending on the nature and location of the site. They include site preparation/ logistics, transportation/set-up, construction supervision, on-site checkout, site-specific permitting/engineering services, working capital, and decontamination/ demobilization. Site preparation is assumed to be by others and no costs are included. The other costs listed above are included elsewhere. It is assumed that mobilization is three days of salaries plus living expenses for all personnel.

Site Preparation/Logistics -- The costs associated with site preparation/logistics include advanced planning and management, detailed site design and development, auxiliary and temporary equipment and facilities, water conditioning, emergency and safety equipment, and site staff support. Soil excavation, feedstock preparation, and feed handling costs are also included. This may be performed by other than HAZCON, but still comprises part of the site remediation costs. Due to the temporary and transient nature of the setup at Douglassville, the costs incurred by EPA for the test are not directly used because they would be misleading. Costs for advanced planning, detailed site design and development, and water conditioning if needed, are assumed to be part of the site prime contractor's expenses, and are not included.

Transportation/Set-Up -- The cost of transportation and set-up includes disassembly of the unit at its present location and transport to a new location. The HAZCON unit is integral with the vehicle automotive function. Auxiliary process equipment is transported on separate flatbed trucks. The costs for transporting the unit to the Douglassville site are not included.

On-site Checkout -- Once the unit has been set up, it is necessary to shakedown the system to ensure that no damage occurred as a result of disassembly, transport, and reassembly. This cost is shown as initial startup and is assumed to be 10% of direct costs calculated on an annual basis.

Working Capital -- Fuel inventory, Chloranan, and cement storage facilities will exist at each site, and as such are semivariable operating costs specific to the site-specific mobilization/demobilization cost element breakdown. It is assumed that all these raw material items will be fully consumed and therefore, no additional charge to the project is added. The storage facilities for these materials are included as part of the direct capital costs.

Decontamination/Demobilization -- With the completion of activities at a specific site, the unit must be decontaminated and demobilized before being transported to its next location. Costs that will accrue to this cost element include field labor and supervision, decontamination equipment and materials, utilities, security, health/safety activities, and site staff support. The demobilization costs included are based upon three days for all personnel.

9.3 OVERALL COST EVALUATION

A primary purpose of this economic analysis is to estimate costs for a commercial-size remediation. It was assumed for this analyses that part of the Douglassville site would be remediated. Due to the short-term nature of the Demonstration Test and the fact that labor and chemical costs dominate the remediation costs, actual costs for the test were not directly used. However, since HAZCON used a small-scale, continuous, commercial unit, the capacity, on-stream factor, and chemical usage during the Demonstration Test was the starting basis for a commercial cleanup estimate. The results of the analysis are presented in Table 9.2.

The results of the analysis show that the cost per ton of soil processed is $206. In comparison to the costs of a future commercial unit, which would be larger, have an improved on-stream factor and probably use less chemicals, the cost per ton of soil processed is very high. The lower values can be obtained based upon HAZCON's recommendations for reducing chemical consumptions 25-50% for attaining an on-stream factor of 90%, and for use of a new 2300 lb/min batch processing unit and might reduce these costs by 50%. This type of analysis will be included in the Applications Analysis Report. Since a 70% on-stream factor with high chemical consumption was actually seen at Douglassville, PA, the costs for this level of operating efficiency were calculated. It should be noted that not all the expenses encountered in a site cleanup are included, such as site preparation and permitting.

As can be seen from the results, 90% of the costs consist of raw materials (cement and Chloranan) and labor.

TABLE 9.2. ESTIMATED COST

CAPITAL COST	
Direct	
Equipment Costs, $	100,000
Chemical Storage, $/ton	2.25
Indirect, $/ton	
Administration (10% Direct Costs)	0.32
Contingency (10% Direct Costs)	0.32
Nondepreciable, $/ton	
Operator Training (3 days)	0.84
Working Capital	--
OPERATING AND MAINTENANCE COSTS	
Variable, $/ton	
Cement	50.00
Chloranan	66.67
Fuel ($1.00/gal-diesel)	1.29
Electricity ($0.04/kwhr)	0.03
Water ($0.80/1000 gal)	0.08
Semivariable, $/ton	
Salaries and Living Expenses	64.70
Equipment Rentals and Consumables	10.36
Analytical Services	6.50
Maintenance (10% Direct Costs)	0.32
Mobilization/Demobilization	1.66
HAZCON and Support Fixed	
Site Preparations	--
Insurance and Taxes (10% Direct Costs)	0.32
Depreciation (10 yrs.)	0.18
TOTALS, $/ton	205.84

TABLE 9.2. NOTES

1. The demonstrated HAZCON MFU capacity is 300 lb/min.

2. It is assumed that 35,400 tons of soil at the Douglassville site was processed. This value derives from continuously operating the demonstrated unit for 6 months at an on-stream factor of 90%. The actual on-stream factor used was 70%.

3. Utilities Consumption Estimates
   1,200 max installed KVA
   Water - 14 gpm
   Diesel Fuel - 8 gph

4. Chemical Consumption
   Cement - 1:1 to contaminated soil
   Chloranan - 1:10 to contaminated soil

5. Labor Estimate - 4 shifts per week - includes overhead
   HAZCON - 1 Manager, $50/hr; 4 Shift Supervisors, $35/hr; 12 Operators, $17.50/hour; 10% OT
   Support Personnel - 1 Manager, $50/hr; 4 Shift Supervisors, $45/hr; 12 Operators, $40/hr; 10% OT
   Others - 1 SSHO, $50/hr; 1 Project Manager, $60/hr; Laboratory Technician (part-time), $40/hr; Office Manager, $40/hr; Secretary, $20/hr
   Living Expenses (motel, food, car rentals, etc.) - HAZCON, $85/D; Support Personnel - Managers and Supervisors $120/D, Operator - local - no charge; Others - $120/D

6. Rental and Consumable Supplies
   Health and Safety consumables and instruments - $450/D

   Office space, office supplies, portable sanitary facilities - $50/day
   Sampling Materials - $40/set
   Heavy Equipment Rental - front-end loaders, backhoes, steam cleaner, drill rig, etc. - $1000/day

7. Site preparation costs, since it would be so interrelated with the overall planning and costs of the Prime Contractor for the entire site, are not included.

8. The costs taken as a fraction of capital and maintenance costs are prorated to the actual time on site.

9. Operator training assumes 3 days of training for HAZCON operators, site preparation operators, the Health and Safety Officer, and sample technician.

REFERENCES

1. Remedial Investigation Report/Feasibility Study of Alternatives, Berks Associates - Douglassville Disposal Site - Union Township, Berks County, PA., EPA Work Assignment No. 59-3651, Contract No. 68-01-6699, June 1986. Prepared by NUS Corporation for Region III.

2. Letter Report, S. Sawyer to P. de Percin, Laboratory Analyses of Screening Samples, July 6, 1987.

3. Demonstration Plan - HAZCON/Douglassville SITE Program, August 31, 1987, EERU Contract No. 68-32-3255. Submitted to P. de Percin, EPA HWERL, Cincinnati, Ohio, August 31, 1987.

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